TOTAL MAXIMUM DAILY LOAD (TMDL)

For

Nutrients, Biochemical Oxygen Demand and Dissolved Oxygen

In the

Caloosahatchee River Basin

Billy Creek (WBID 3240J)
Ninemile Canal (WBID 3237D)
Daughtrey Creek (WBID 3240F)
Lake Hicpochee (WBID 3237C)

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EPA
United States
Environmental Protection
Agency

Region 4
serving the southeast

In compliance with the provisions of the Federal Clean Water Act, 33 U.S.C §1251 et. seq., as amended by the Water Quality Act of 1987, P.L. 400-4, the U.S Environmental Protection Agency is hereby establishing these Total Maximum Daily Loads (TMDLs) for nutrients, biochemical oxygen demand and dissolved oxygen in the Caloosahatchee River Basin (WBIDs 3240J, 3240F, 3237C, and 3237D). Subsequent actions must be consistent with this TMDL.

James D. Giattina, Director
Water Management Division

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Date

Concurrences:

E. Belk E.L.B. 3/7/06

A. Godfrey 3/9/04

A. Bartlett 3/10

G. Mitchell

J. Giattina 3/14/06

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LIST OF ABBREVIATIONS

AWT	Advanced Waste Treatment
BMP	Best Management Practices
BPJ	Best Professional Judgment
CFS	Cubic Feet per Second
CFU	Colony Forming Units
DEM	Digital Elevation Model
DMR	Discharge Monitoring Report
EPA	Environmental Protection Agency
FAC	Florida Administrative Code
GIS	Geographic Information System
HUC	Hydrologic Unit Code
LA	Load Allocation
MGD	Million Gallons per Day
MOS	Margin of Safety
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer Systems
NASS	National Agriculture Statistics Service
NLCD	National Land Cover Data
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSTD	Onsite Sewer Treatment and Disposal Systems
PLRG	Pollutant Load Reduction Goal
Rf3	Reach File 3
RM	River Mile
STORET	STORage RETrieval database
TBN	Total Bioavailable Nitrogen
TBP	Total Bioavailable Phosphorus
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WBID	Water Body Identification
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WMP	Water Management Plan

SUMMARY SHEET
Total Maximum Daily Load (TMDL)

1. 303(d) Listed Waterbody Information

State: Florida

Major River Basin: Caloosahatchee River Basin (HUC 03090205)

1998 303(d) Listed Waterbodies for TMDLs addressed in this report:

WBID	Segment Name and Type	County	Constituents(s)
3240J	Billy Creek (estuarine)	Lee	Dissolved Oxygen
3237D	Ninemile Canal (freshwater)	Hendry	Dissolved Oxygen, Nutrients, Biochemical Oxygen Demand
3240F	Daughtrey Creek (freshwater)	Charlotte, Lee	Dissolved Oxygen
3237C	Lake Hicpochee (freshwater)	Glades, Hendry	Nutrients

2. TMDL Endpoints (i.e., Targets)

The targets for the Dissolved Oxygen (D.O.) TMDLs in Billy and Daughtrey Creeks are based on the State of Florida's water quality criteria for D.O., which require that in no case should the concentration be less than 5 mg/L in freshwater streams. For marine waters, the dissolved oxygen should not be less than 5.0 mg/l in a 24-hour period, and it should never be less than 4.0 mg/l. Model simulations indicate that reductions in Biochemical Oxygen Demand (BOD) loadings from the watershed result in attainment of the D.O. criteria.

In Ninemile Canal, the BOD, total phosphorus and total nitrogen loads estimated under natural land covers were targeted for the nutrient and DO TMDLs on the premise that these loads would not cause an imbalance in the natural populations of flora and fauna, nor would they cause nuisance conditions that depress DO below natural levels.

The endpoint for the nutrient TMDL in Lake Hicpochee (WBID 3237C) is a total phosphorus concentration of 0.035 mg/l (interpretation of narrative standards).

3. Allocations for D.O./BOD TMDLs.

WBID	Parameter	TMDL (lb/day)	LA (lb/day)	WLA[1] Continuous (lb/day)	WLA[1] MS4	MOS[3] (lb/day)	Percent Reduction[4]
3240F	BOD	176	176	N/A[2]	N/A[2]	implicit	16%
3240J	BOD	305	305	N/A[2]	29%	implicit	29%
3237D	BOD	731	731	N/A[2]	N/A[2]	implicit	10%

Notes:
1. WLA component is separated into a load from continuous NPDES facilities (e.g., WWTPs) and a load from MS4s. Currently, there are no continuous discharge facilities or MS4 areas in WBIDs 3240F or 3237D. WBID 3240J is affected by Phase I MS4 permit #FL000035, which covers Lee County, the City of Cape Coral, and the City of Fort Myers. There are no continuous discharge facilities currently discharging to the surface waters of WBID 3240J.
2. N/A = not applicable.
3. Represents a 10% Margin of Safety.
4. Percent reduction in total BOD loading from current conditions to achieve the D.O. standard.

4. Allocations for Nutrient TMDLs.

WBID	Parameter	TMDL (lb/day)	LA[1] (lb/day)	WLA[1] Continuous (mg/l)	WLA[1] MS4	MOS (lb/day)	Percent Reduction[4]
3237D	TBN[2]	188	188	N/A[3]	N/A[3]	implicit	57%
	TBP[2]	39	39	N/A[3]	N/A[3]	implicit	59%

Notes:

1. Represents natural background sources. WLA component is separated into a load from continuous NPDES facilities (e.g., WWTPs) and a load from MS4s. Currently, there are no continuous facilities or MS4 areas in WBID 3237D.
2. TBN= Total Bioavailable Nitrogen; TBP= Total Bioavailable Phosphorus.
3. N/A = not applicable.
4. Percent reduction in TBN or TBP loading from current conditions to meet the natural conditions standard.

WBID	Parameter	TMDL (mg/l)	LA (mg/l)	WLA[1] Continuous (mg/l)	WLA[1] MS4	MOS	Percent Reduction
3237C	Total Phosphorus	0.035 mg/l	0.035 mg/l	N/A[2]	N/A[2]	implicit	91%

Notes:

1. WLA component is separated into a load from continuous NPDES facilities (e.g., WWTPs) and a load from MS4s. Currently, there are no continuous discharge facilities or MS4 areas in WBID 3237C.
2. N/A = not applicable
3. Percent reduction from current conditions to achieve the target concentration for phosphorus.

5. **Endangered Species (yes or blank):** Yes

6. **EPA Lead on TMDL (EPA or blank):** EPA

7. **TMDL Considers Point Source, Nonpoint Source, or both:** Both

8. **Major NPDES Discharges to surface waters addressed in EPA TMDL:** None

TOTAL MAXIMUM DAILY LOAD (TMDL) FOR NUTRIENTS, BIOCHEMICAL OXYGEN DEMAND AND DISSOLVED OXYGEN in THE CALOOSAHATCHEE RIVER BASIN (WBIDS 3240J, 3237D, 3240F, 3237C)

1. INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology-based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those water bodies that are not meeting water quality standards. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water quality based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources (USEPA, 1991).

The State of Florida Department of Environmental Protection (FDEP) has developed 303(d) lists since 1992. The process by which Florida implements section 303(d) requirements is set forth in the Florida Watershed Restoration Act (FWRA) of 1999 (s. 403.067, Florida Statutes). The FDEP list of impaired waters in each basin, referred to as the "Verified List", is also adopted pursuant to the FWRA (Subsection 403.067[4], Florida Statutes). However, the FWRA also states that all previous Florida 303(d) lists were for planning purposes only and directed the Department to develop, and adopt by rule, a new science-based methodology to identify impaired waters. After a long-rule-making process, the Florida Environmental Regulation Commission adopted the new methodology as Chapter 62-303, Florida Administrative Code (Identification of Impaired Surface Waters Rule, or IWR), in April 2001. The TMDLs developed in this report are for impaired waters that are on the 1998 303(d) list but not the verified list. They are being established pursuant to EPA commitments in the 1998 Consent Decree in the Florida TMDL lawsuit (Florida Wildlife Federation, et al. v. Carol Browner, et al., Civil Action No. 4: 98CV356-WS, 1998).

FDEP developed a statewide, watershed-based approach to water resource management. Following this approach, water resources are managed on the basis of natural boundaries, such as river basins, rather than political boundaries. The watershed management approach is the framework DEP uses for implementing TMDLs. The state's 52 basins are divided into 5 groups. Water quality is assessed in each group on a rotating five-year cycle. The Group 3 basin includes waters in the basins of the Caloosahatchee River, Choctawhatchee Bay and River, Saint Andrews Bay, Peace River, Sarasota Bay, Myakka River, Lake Worth Lagoon/Palm Beach Coast, and Saint Johns River. Group 3 waters were first assessed in 2002 with plans to revisit water management issues in 2007. FDEP established five water management districts (WMD) responsible for managing ground and surface water supplies in the counties encompassing the districts. The Caloosahatchee River is located in the South Florida Water Management District (SFWMD).

For the purpose of planning and management, the WMDs divided the district into planning units defined as either an individual primary tributary basin or a group of adjacent primary tributary basins with similar characteristics. These planning units contain smaller, hydrological based units called drainage basins, which are further divided into "water segments". A water segment usually contains only one unique waterbody type (stream, lake, cannel, etc.) and is about 5 square miles. Unique numbers or waterbody identification (WBIDs) numbers are assigned to each water segment.

2. PROBLEM DEFINITION

Florida's final 1998 Section 303(d) list identified numerous WBIDs in the Caloosahatchee River Basin as potentially not supporting water quality standards (WQS). After assessing all readily available water quality data, EPA is responsible for determining whether TMDLs are needed for nutrients, biochemical oxygen demand (B.O.D.) and/or dissolved oxygen (D.O.) in four WBIDs of the basin (Table 1). The geographic locations of these listed WBIDs are shown in Figure 1. Requests to de-list WBID 3240F (Daughtrey Creek) and WBID 3240J (Billy Creek) for nutrients will be approved.

Table 1. Nutrient, BOD and DO TMDLs Developed By EPA in Caloosahatchee River Basin.

WBID	Name	Planning Unit	Parameter of Concern
3240J	Billy Creek	Orange River	D.O.
3237D	Ninemile Canal	East Caloosahatchee	D.O./BOD and Nutrients
3240F	Daughtrey Creek	Caloosahatchee Estuary	D.O.
3237C	Lake Hicpochee	East Caloosahatchee	Nutrients

The waterbodies listed in Table 1 are Class III waters with the designated use of recreation, and propagation and maintenance of a healthy, well-balanced population of fish and wildlife. Billy Creek is estuarine in nature, while Ninemile Canal, Lake Hicpochee, and Daughtrey Creek are freshwater.

To determine the status of surface water quality in the state, three categories of data – chemistry data, biological data, and fish consumption advisories – were evaluated to determine potential impairments. The level of impairment is defined in the Identification of Impaired Surface Waters Rule (IWR), Section 62-303 of the Florida Administrative Code (F.A.C.). The IWR defines the threshold for determining if waters should be included on the state's planning list and verified list. Potential impairments are determined by assessing whether a waterbody meets the criteria for inclusion on the planning list. Once a waterbody is on the planning list, additional data and information will be collected and examined to determine if the water should be included on the verified list.

The format of the remainder of this report is as follows: Chapter 3 is a general description of the impaired watershed; Chapter 4 describes the water quality standard and target criteria for the TMDL; and Chapter 5 describes the development of the TMDL.

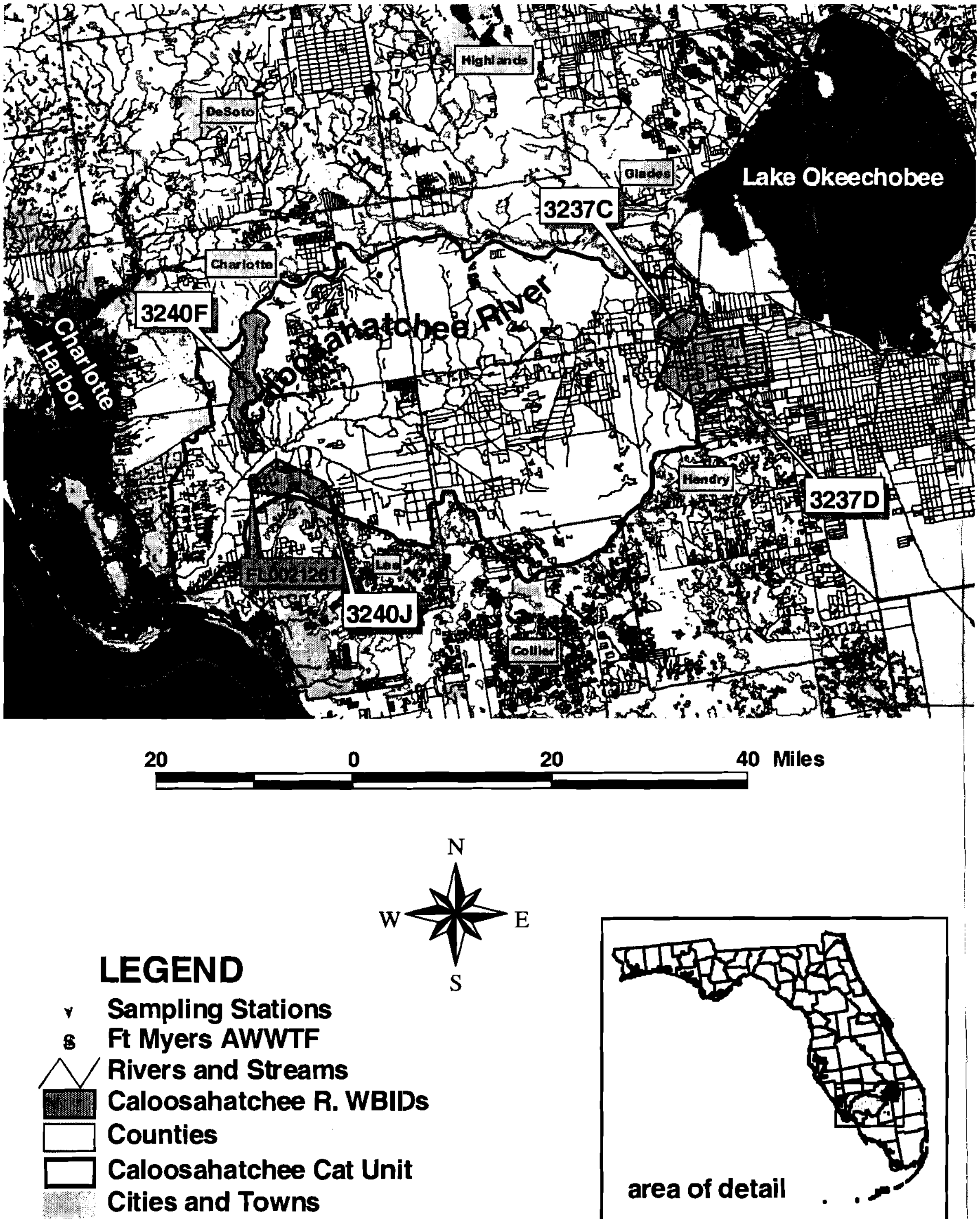

Figure 1. Location of 303(d) listed WBIDs in the Caloosahatchee River Basin.

3. WATERSHED DESCRIPTION

The Caloosahatchee River basin is defined by USGS Hydrologic Unit Code (HUC) 03090205. The following description of the impaired watersheds is from the Basin Status Report (FDEP, 2003). This document should be consulted for additional details.

The Caloosahatchee Basin encompasses approximately 1,400 square miles of southern Florida and serves as the major source of freshwater in the Lower West Coast Region (Figure 1). The entire basin covers significant portions of four counties and is divided into five planning units: East Caloosahatchee River, West Caloosahatchee River, Orange River, Telegraph Swamp, and Caloosahatchee Estuary. The hydrology and land uses of the Caloosahatchee Basin have undergone significant modification in the last century. Originally, the Caloosahatchee was a shallow, meandering river that flowed westward from its headwaters near Lake Hicpochee to San Carlos Bay in the Gulf of Mexico (Haag et al, 1996). Dredging activities connected the Caloosahatchee to Lake Okeechobee in 1884. Today, the Caloosahatchee River is part of the Okeechobee Waterway that links the Gulf of Mexico to the Atlantic Ocean. The freshwater portion of the river has been channelized into the C-43 canal in order to accommodate navigation and provide flood control. Starting in the 1930's, three locks or water control structures were constructed: the Moore Haven Lock (S-77), Ortona Lock (S-78), and the Franklin Lock (S-79). The Franklin lock also serves as a salinity barrier dividing the upstream freshwater and downstream tidal portions of the Caloosahatchee. Most of the freshwater entering the Caloosahatchee estuary flows through Franklin Lock. Currently, somewhere around half of the water that reaches S-79 is water that had passed through S-77 from Lake Okeechobee (Mark Shafer, personal communication). In 1995, the Caloosahatchee was recognized as an estuary of national significance and included as part of the National Estuary Program. Several studies have been developed to investigate the effects of altered freshwater inputs to the estuary, and to determine alternative management options.

Much of the natural habitat in the basin has been converted to other uses (Table 2). Agriculture is a major landuse in the freshwater part of the basin, and its importance is expected to increase into the future. The dominant crops are citrus and sugarcane. Many of the tributaries to the Caloosahatchee are channelized and serve as agricultural canals and drainage ditches. Along the coast, the tidal Caloosahatchee is affected by urban areas including Fort Myers, Cape Coral, and North Fort Myers. The Caloosahatchee also serves as a potable water supply for Lee County and the city of Fort Myers. The Cape Coral/Fort Myers urban area is one of the fastest growing in the United States. Hydrologic modification associated with urban and agricultural development has significantly impacted the water quantity and quality of the basin.

Table 2. Land Cover Distribution[1] (acres) in the Caloosahatchee River Basin.

WBID	Residential	Com, Ind, Public[2]	Agriculture	Rangeland[3]	Forest	Water	Wetlands	Barren & extractive	Transp & utilities	Total (acres)
3240J	3311	3536	1470	452	1935	92	1049	419	543	12807
3237D	451	68	30887	578	1572	797	3040	162	638	38193
3240F	1381	107	3600	1728	4611	15	4599	269	276	16588
3237C	5	0.0	1946	102	9	197	3580	157	143	6137

Notes:
1. Acreage represents the land use distribution in the WBID and not the entire drainage area.
2. Public lands include urban and recreational areas.
3. Rangeland includes shrubland, grassland, and herbaceous land covers.
4. Data source for is 1995 land cover from the SFWMD.

The soils are generally coarse and sandy, allowing high infiltration rates, and the upper aquifer system is known to have relatively high conductivity. There is high hydraulic contact between the upper aquifers and surface water, so the water table is near the surface in most of the basin. Due to the permeable soils, the high conductivity of the aquifer, and the extensive network of drainage canals, rainfall events affect rapid responses both above and below ground. This also means that any pesticides, herbicides, or fertilizers applied to the land are shared between surface and groundwater.

3.1 WBID 3240J Billy Creek

Billy Creek is a Class 3 estuary that lies within the Orange River Planning Unit. It joins the Caloosahatchee River just above US41. Billy Creek, WBID 3240J, is listed on the 1998 303(d) list for nutrients and dissolved oxygen, and is considered potentially impaired for biology, copper, DO, and fecal coliform under the 2001 Impaired Waters Rule.

In WBID 3240J, the predominant land uses are high and medium density residential (26%) and commercial/industrial (28%) developments, with lesser amounts of forest (15%), agriculture (11%), and wetlands (8%; see Table 2). Billy Creek receives stormwater from much of East Fort Myers, and many of the water quality problems in the area are linked to the urban and suburban landuses (FDEP, 2003). Figure 2 shows an example of suburban development along Billy Creek looking downstream from Veronica Shoemaker Boulevard, between Brookhill Drive and Marion Street. Figures 3 and 4 show Billy Creek at Ortiz Avenue.

Figure 2. Billy Creek looking downstream from Veronica Shoemaker Blvd (Palmetto Ave).

Figure 3. Billy Creek facing downstream from Ortiz Avenue.

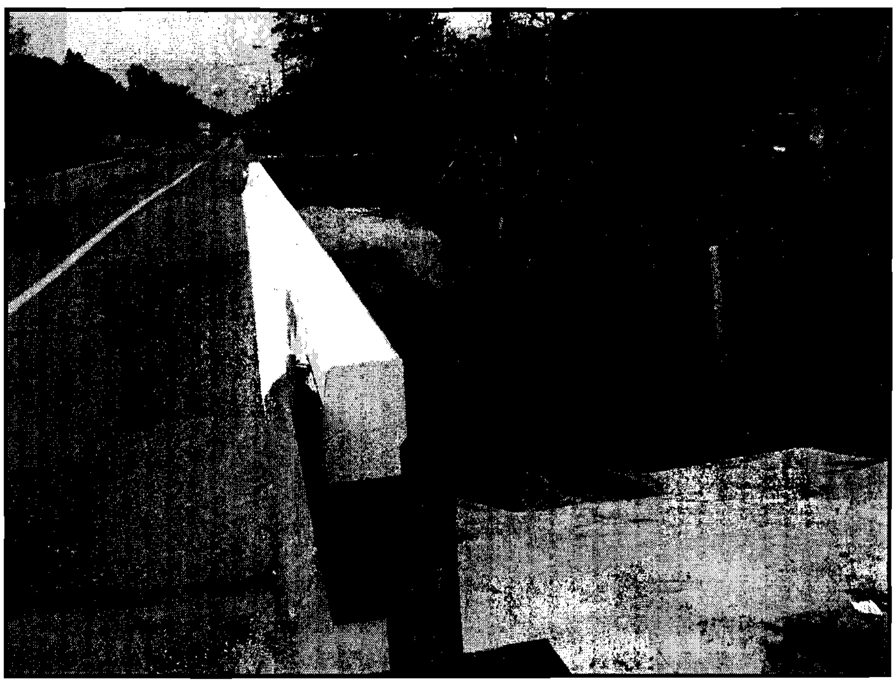

Figure 4. Stormwater inputs to Billy Creek at Ortiz Avenue.

3.2 WBID 3237D Ninemile Canal

WBID 3237D, Ninemile Canal, is a Class 3 freshwater canal that is included in the East Caloosahatchee Planning Unit. The canal mainly serves for agricultural drainage. Ninemile Canal flows westward from the City of Clewiston, through agricultural areas, and then passes through the northern part of WBID 3237D before emptying into Lake Hicpochee. The East Caloosahatchee has many problems with low dissolved oxygen and elevated metals, which are assumed to be caused- at least in part- by agricultural activity. Ninemile Canal is listed on the 1998 303(d) list for nutrients, D.O., BOD, and fecal and total coliforms. It is considered potentially impaired for D.O. under the 2001 Impaired Waters Rule.

Agriculture is by far the dominant activity in WBID 3237D, accounting for approximately 81% of the landcover. Some remaining patches of forest (4%) and wetlands (8%) remain (Table 2), but numerous canals and flow structures are present. The flow patterns in the WBID have been substantially altered from their natural state to the extent that the downstream end of WBID 3237D needs to be pumped into Lake Hicpochee. Due to highly permeable soils and relatively flat topography, groundwater is a major influence on the surface waters of the WBID.

Figure 5 and Figure 6 are views of WBID 3237D, Ninemile Canal, showing adjacent agricultural areas. The flat topography and aquatic plants are factors that result in low flows.

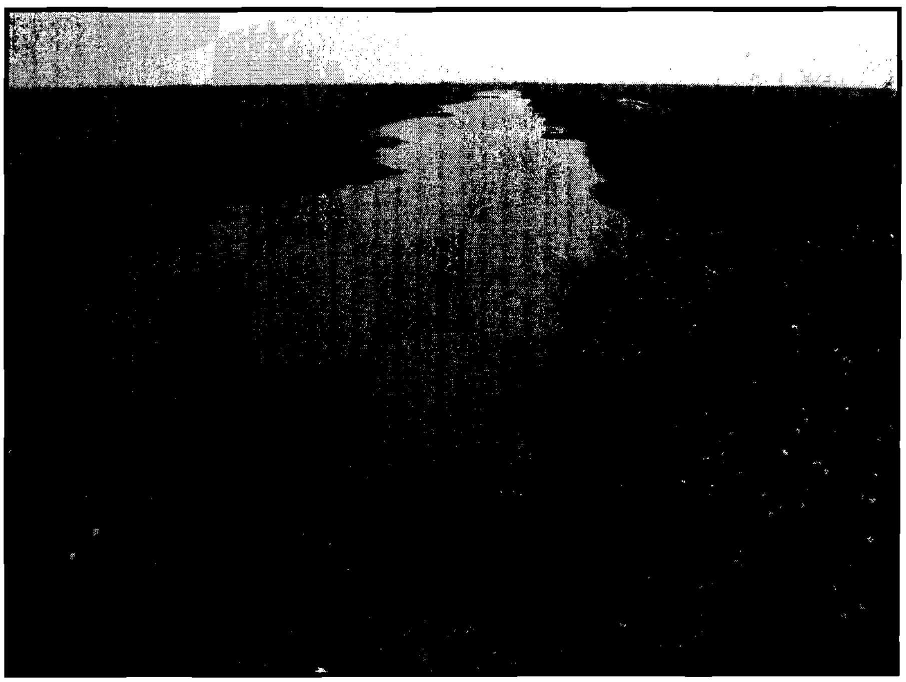

Figure 5. View of WBID 3237D, facing east.

Figure 6. View of WBID 3237D, facing west.

3.3 WBID 3240F Daughtrey Creek

WBID 3240F, Daughtrey Creek, is a class 3 freshwater stream that lies in the Caloosahatchee Estuary Planning Unit. Daughtrey Creek is included on the 1998 303(d) list for nutrients and D.O., although it is only considered potentially impaired for D.O. under the 2001 Impaired Waters Rule.

The headwaters of Daughtrey Creek are in a relatively flat, wooded wetland area. The stream then flows through significant agricultural and urbanized areas before meeting up with the Caloosahatchee River northeast of Fort Myers. Landcover in WBID 3240F is approximately 28% forest, 28% wetlands and 22% agriculture, with lesser amounts of rangeland (10.4%) and residential (8.3%) areas (Table 2). Daughtrey Creek's water quality issues have been attributed to urban and suburban landuses, including poorly flushed residential canals and migration of pollutants from upstream tributaries (FDEP, 2003). Daughtrey Creek had excellent Stream Condition Index (SCI) scores in 1996 and 1998. The Stream Condition Index (SCI) rates the health of benthic macroinvertebrate communities against reference conditions. It passed the 1996 biological evaluation and was considered healthy.

Figure 7 shows Daughtrey Creek at Bayshore Road, looking upstream. Figure 8 is a downstream view of Daughtrey Creek at Slater Road. As can be seen in both images, Daughtrey Creek receives stormwater runoff and is highly colored.

Figure 7. Daughtrey Creek, WBID 3240F, at Bayshore Road.

Figure 8. Daughtrey Creek, WBID 3240F, at Slater Road.

3.4 WBID 3237C Lake Hicpochee

WBID 3237C, Lake Hicpochee, is a Class 3 freshwater lake and wetland complex that lies within the East Caloosahatchee Planning Unit. Originally, the Caloosahatchee was a shallow, meandering river that flowed westward from its headwaters near Lake Hicpochee (Haag et al, 1996). After a canal was dredged in the late 1800's, Lake Hicpochee was connected to Lake Okeechobee. A channel effectively bisects Lake Hicpochee into two marshes. The C-19 Canal connects to the C-43 Canal in Lake Hicpochee, and an irrigation canal connects C-43 with lift pumps on the south side of the lake. Both the C-43 and C-19 Canals were dug as part of the South Florida Flood Control Project. Lake Hicpochee has been significantly impacted by its unnatural connection to Lake Okeechobee. Lake Hicpochee WBID 3237C is listed on the 1998 303(d) list for nutrients, and is considered potentially impaired for lead, but not dissolved oxygen (D.O.), under the 2001 Impaired Waters Rule.

The East Caloosahatchee Planning Unit is the most heavily farmed in the Caloosahatchee Basin. In WBID 3237C, the predominant land uses are wetlands (58%) followed by agriculture (32%; see Table 2). Lake Hicpochee receives agricultural drainage from the surrounding areas, including in flows from Lake Okeechobee. Figure 2 shows a view of Lake Hicpochee from the east bank of the C-43 canal.

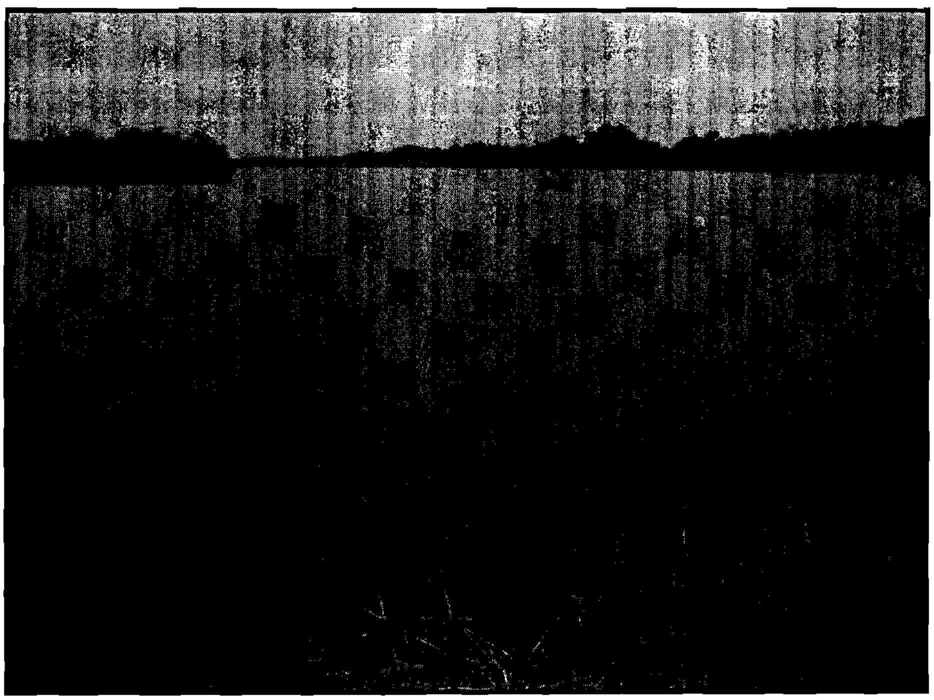

Figure 9. View of Lake Hicpochee, WBID 3237C, from the east bank.

4. WATER QUALITY STANDARDS AND TARGET IDENTIFICATION

Waterbodies in the Caloosahatchee River Basin are Class III fresh and marine waters, with a designated use of recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The water quality criteria for protection of Class III waters are established by the State of Florida in the Florida Administrative Code (F.A.C.), Section 62-302.530. The individual criteria should be considered in conjunction with other provisions in water quality standards, including Section 62-302.500 F.A.C. [Surface Waters: Minimum Criteria, General Criteria] that apply to all waters unless alternative criteria are specified in F.A.C. Section 62-302.530. In addition, unless otherwise stated, all criteria express the maximum not to be exceeded at any time. While the State of Florida does not have numeric criteria for nutrients, a narrative criterion exists as described below. The specific criteria for the impaired WBIDs addressed in this TMDL are as follows:

4.1 Nutrients (Freshwater and Marine)

The discharge of nutrients shall continue to be limited as needed to prevent violations of other standards contained in this chapter [Section 62.302 F.A.C.]. In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora and fauna [Section 62.302.530 F.A.C.]

Because the State of Florida does not have numeric criteria for nutrients, chlorophyll and D.O. levels are used to indicate whether nutrients are present in excessive amounts.

4.2 Dissolved Oxygen

Freshwater: Dissolved Oxygen (D.O.) shall not be less than 5.0 (milligrams/liter). Normal daily and seasonal fluctuations above these levels shall be maintained.

Marine: Dissolved Oxygen (D.O.) shall not be less than 5.0 (milligrams/liter) in a 24-hour period and shall never be less than 4.0. Normal daily and seasonal fluctuations above these levels shall be maintained.

4.3 Biochemical Oxygen Demand (Freshwater and Marine)

Biochemical Oxygen Demand (B.O.D.) shall not be increased to exceed values which would cause dissolved oxygen to be depressed below the limit established for each class and, in no case, shall it be great enough to produce nuisance conditions.

4.4 Natural Conditions

In addition to the standards for nutrients, D.O. and B.O.D. described above, Florida's standards include provisions that address waterbodies which do not meet the standards due to "natural background" conditions.

"'Natural Background' shall mean the condition of waters in the absence of man-induced alterations based on the best scientific information available to the Department. The establishment of natural background for an altered waterbody may be based upon a similar unaltered waterbody or on historical pre-alteration data." [Section 62-302.200(15) FAC].

Florida standards also state at 62-302.300(15) FAC that "Pollution which causes or contributes to new violations of water quality standards or to continuation of existing violations is harmful to the waters of this State and shall not be allowed. Waters having water quality below the criteria established for them shall be protected and enhanced. However, the Department shall not strive to abate natural conditions."

4.5 TMDL targets

For Billy and Daughtrey Creeks, the TMDL targets are the BOD loads that achieve the DO standard in each stream. For Ninemile Canal, the BOD, total phosphorus and total nitrogen loads estimated under natural land covers were targeted for the nutrient and DO TMDLs on the premise that these loads would not cause an imbalance in the natural populations of flora and fauna, nor would they cause nuisance conditions that depress DO below natural levels. For Lake Hicpochee, the nutrient target (for total phosphorus) was developed to attain a Trophic State Index (TSI) <60. The TSI is described further in section 5.3.3. EPA determined that this is a reasonable interpretation of the narrative nutrient standard.

5. NUTRIENT/D.O. TMDL

This section of the report describes the development of the nutrient, biochemical oxygen demand and dissolved oxygen TMDLs for Billy Creek (WBID 3240J), Ninemile Canal (WBID 3237D), Daughtrey Creek (WBID 3240F), and Lake Hicpochee (WBID 3237C). First, an assessment of the available water quality data is discussed.

5.1 Water Quality Data Assessment and Deviation from Target

Table 3 provides a list of the monitoring stations at which monitoring data was gathered within the impaired WBIDs. Each station is identified, and the time period of record for the individual stations is provided. Data collected at these monitoring stations during the Group 3 listing cycle (i.e. January 1997 through December 2004) and any data collected in 2005, if available, are considered in the data assessment and TMDL analysis. However, when no recent data are available for a particular parameter, data collected prior to 1997 are considered.

Table 3. Water Quality Stations in the impaired WBIDs.

WBID	STATION	STATION NAME	DATES	
			FIRST	LAST
3237C	21FLFTM 28020245FTM	Lake Hicpochee (LH1)	1/9/01	11/4/03
3237C	21FLFTM 28020246FTM	Lake Hicpochee (LH2)	1/9/01	11/4/03
3237C	21FLFTM 28020247FTM	Lake Hicpochee (LH3)	1/9/01	11/4/03
3237C	21FLFTM 28020248FTM	C19 Canal at Lake Hicpochee	1/9/01	11/4/03
3237D	21FLA/FLFTM 28020138	9 Mi Canal 3 Mi S. Moorehaven	10/15/03	10/15/03
3237D	21FLFTM 28020139	9 Mi Canal 4.5 Mi S. Moorehaven	2/22/99	5/7/03
3237D	21FLFTM 28020254FTM	US 27 Canal (1.3 Mi north of Nine Mile Canal)	2/22/99	10/15/03
3240F	21FLA 28020231	Daughtrey Creek @ Bright Rd. N Ft. Myers	7/28/98	7/28/98
3240F	21FLEECO20-29GR	Daughtrey Creek- Nalle Grade Bridge	1/16/97	12/10/02
3240F	21FLEECO20-9GR	Daughtrey Creek- SR 78	1/16/97	12/19/02
3240F	21FLEECO20A-11GR	Daughtrey Creek- E. Branch SR 78	7/31/97	12/19/02

WBID	STATION	STATION NAME	DATES	
			FIRST	LAST
3240F	21FLEECO20A-19GR	Daughtrey Creek- E. Branch I-75	1/23/97	12/2/02
3240F	21FLEECOGATRGR91	Gator Slough- I-75	1/23/97	12/2/02
3240J	21FLEECOBILLGR20	Billy Creek at Palmetto Ave., Fort Myers	1/28/97	12/17/02
3240J	21FLEECOBILLGR60	Billy Creek at Ortiz Ave, Fort Myers	1/28/97	12/17/02
3240J	21FLA/FLFTM 28020233	Billy's Creek at Marsh Ave, Fort Myers	2/24/97	2/13/02

Biology

The biology of Billy Creek, WBID 3240J, was sampled in August 1996, February 1997, July 1999, October 1999, and March 2000 (FDEP, 2003; see Table 4). Biological assessments typically involve evaluating biological communities to determine if the waterbodies are meeting their designated use to support healthy aquatic life. The Stream Condition Index (SCI), which rates the health of benthic macroinvertebrate communities against reference conditions, was rated overall as "good" for Billy Creek through July 1999. In October 1999, the SCI of Billy Creek was measured at two stations, one located at Ortiz Avenue and the other at Marsh Avenue. Billy Creek at Marsh Avenue was rated with a "Poor" SCI in October 1999, but this same station had previously had "Good" SCI scores. Billy Creek at Ortiz Avenue was rated as "Good" in October 1999, but when the station was re-evaluated in March 2000, the score had degraded to "Very Poor" condition. It was for the reason that the station was listed as potentially impaired. Most of the water quality data for Billy Creek were collected at the Palmetto Avenue and Ortiz Avenue stations.

The biology of Daughtrey Creek was evaluated at the Bright Road sampling station in the late 1990's. The station had "excellent" SCI scores in August 1996 and July 1998. It passed the biological reconnaissance performed in 1996 and was considered healthy (FDEP, 2003).

Table 4. SCI Evaluations for Billy and Daughtrey Creeks.

Station Name	Station Number	Date	SCI Score	SCI Evaluation
Billy Creek at Marsh Ave.	28020233	8/21/1996	25	Good
Billy Creek at Marsh Ave.	28020233	2/24/1997	25	Good
Billy Creek at Marsh Ave.	28020233	7/28/1999	23	Good
Billy Creek at Marsh Ave.	CANALS002	10/12/1999	19	Poor
Billy Creek at Ortiz Ave.	CANALS003	10/12/1999	25	Good
Billy Creek at Ortiz Ave.	CANALS003	10/12/1999	25	Good
Billy Creek at Ortiz Ave.	CANALS003	3/14/2000	9	Very Poor
Billy Creek at Ortiz Ave.	CANALS003	3/14/2000	11	Very Poor
Daughtrey Creek at Bright Rd.	28020231	8/7/1996	27	Excellent
Daughtrey Creek at Bright Rd.	28020231	7/28/1998	29	Excellent

Water Quality Data

Summaries of the available water quality data, collected at any station in the impaired WBIDs between 1997 to present, are available in the following tables. Table 5 summarizes the data for WBID 3240J (Billy Creek), Table 6 for WBID 3237D (Ninemile Canal), Table 7 for WBID 3240F (Daughtrey Creek), and Table 8 for WBID 3237C (Lake Hicpochee). Note that total nitrogen was estimated as Total Kjeldahl Nitrogen (TKN) + Nitrate Nitrite (NO_3O_2).

Table 5. Water Quality Data for WBID 3240J (Billy Creek).

Parameter	Obs	Min	Max	Mean	StDev	Median
BOD, carbonaceous 5-day (mg/l)	145	1.0	8.0	2.4	1.4	1.8
Chlorophyll A, corrected (μg/l)	81	1.0	33.5	3.9	5.1	2.0
Color (PCU)	54	48	188	112	40	106
Conductance (mohm)	143	290	10300	972	1212	700
Dissolved Oxygen (mg/l)	143	0.5	8.0	3.9	1.7	3.8
Nitrogen Ammonia as N (mg/l)	148	0.01	1.55	0.23	0.34	0.07
Nitrite Nitrogen as N (mg/l)	145	0.00	0.23	0.02	0.04	0.01
Nitrate Nitrogen as N (mg/l)	145	0.01	1.30	0.15	0.19	0.09
Nitrate Nitrite (mg/l)	148	0.01	1.30	0.17	0.21	0.10
Nitrogen, Total as N, estimated (mg/l)	148	0.02	3.06	1.04	0.64	0.92
pH (su)	143	6.9	8.5	7.5	0.2	7.5
Temperature (Celsius)	143	10.4	31.0	23.5	4.7	24.2
Nitrogen Kjeldahl as N (mg/l)	148	0.01	2.88	0.87	0.57	0.77
P in total Orthophosphate as P (mg/l)	145	0.00	0.46	0.09	0.10	0.05
Phosphorus Total as P (mg/l)	146	0.01	0.95	0.17	0.1	0.2
Total Suspended Solids (TSS;mg/l)	145	0.5	441.0	11.5	39.1	5.0
Turbidity (NTU)	148	0.4	69.0	4.0	6.2	3.0

1. Obs= number of observations; Max= maximum value; Min= mininum value; Mean= average value; StDev= standard deviation; Median= median value.
2. Some values contributing to these statistics are below the practical quantification or reporting limit; in those instances the value was left as the reported limit. Please see original data for associated remark codes.

Table 6. Water Quality Data for WBID 3237D (Ninemile Canal).

Parameter	Obs	Min	Max	Mean	StDev	Median
BOD, carbonaceous 5-day (mg/l)	10	1	5.7	2.4	1.5	2.0
Chlorophyll A (μg/l)	55	1	310	15.8	43.2	3.5
Color (PCU)	47	50	280	104	43	100
Conductance (mohm)	55	379	1607	838	273	816
Dissolved Oxygen (mg/l)	53	0.1	7.0	1.8	1.7	1.1
Nitrogen Ammonia as N (mg/l)	53	0.02	1.69	0.28	0.41	0.08
Nitrate Nitrite (mg/l)	57	0.004	13.0	0.34	1.74	0.02
Nitrogen, Total as N, estimated (mg/l)	56	0.99	17.20	2.51	2.16	2.11
Nitrogen Kjeldahl as N (mg/l)	57	0.10	4.20	2.17	0.87	2.00
pH (su)	54	5.80	7.65	7.01	0.35	7.02
P in dissolved Orthophosphate (mg/l)	55	0.01	0.43	0.09	0.10	0.06
Water Temperature (Celsius)	54	15.20	30.49	24.72	3.98	25.54
Total Organic Carbon (mg/l)	53	19.00	44.00	29.45	6.87	28.00
Total Suspended Solids (TSS;mg/l)	33	0.60	28.00	5.20	5.98	3.00
Turbidity (NTU)	47	0.30	11.10	2.79	2.49	1.90

1. Obs= number of observations; Max= maximum value; Min= mininum value; Mean= average value; StDev= standard deviation; Median= median value.
2. Some values contributing to these statistics were below the practical quantification or reporting limit; in those instances the value was left as the reported limit. Please see original data for any associated remark codes.

Table 7. Water Quality Data for WBID 3240F (Daughtrey Creek).

Parameter	Obs	Min	Max	Mean	StDev	Median
BOD, carbonaceous 5-day (mg/l)	278	0.8	7.4	2.1	1.09	1.7
Chlorophyll A (µg/l)	142	1	150	8.8	14.7	4.5
Color (PCU)	75	27	357	101	68	80
Conductance (mohm)	264	92	17700	829	1340	555
Dissolved Oxygen (mg/l)	264	0.1	8.3	3.9	1.2	3.8
Nitrogen Ammonia as N (mg/l)	279	0.01	0.93	0.07	0.10	0.02
Nitrate Nitrite (mg/l)	281	0.010	1.1	0.05	0.12	0.02
Nitrogen, Total as N, estimated (mg/l)	279	0.02	3.24	0.86	0.54	0.77
Nitrogen Kjeldahl as N (mg/l)	279	0.01	2.57	0.80	0.51	0.72
pH (su)	264	6.61	7.80	7.39	0.20	7.40
P in total Orthophosphate as P (mg/l)	280	0.00	1.90	0.05	0.15	0.01
Water Temperature (Celsius)	266	12.00	31.00	23.45	4.01	24.00
Phosphorus Total as P (mg/l)	279	0.01	1.62	0.12	0.16	0.06
Total Suspended Solids (TSS;mg/l)	278	1.00	503.00	10.66	35.13	4.00
Turbidity (NTU)	281	0.50	94.00	2.95	6.16	1.80

1. Obs= number of observations; Max= maximum value; Min= mininum value; Mean= average value; StDev= standard deviation; Median= median value.
2. Some values contributing to these statistics were below the practical quantification or reporting limit; in those instances the value was left as the reported limit. Please see original data for any associated remark codes.

Table 8. Water Quality Data for WBID 3237C (Lake Hicpochee).

Parameter	Obs	Min	Max	Mean	StDev	Median
BOD, carbonaceous 5-day (mg/l)	8	2.1	6.7	4.4	1.5	4.2
Chlorophyll A (µg/l)	88	1	389	27	45	18.5
Color (PCU)	71	40	240	91	46	80
Conductance (mohm)	92	327	1033	553	135	551
Dissolved Oxygen (mg/l)	92	0.9	12.8	6.0	2.6	5.9
Nitrogen Ammonia as N (mg/l)	75	0.02	0.53	0.11	0.11	0.07
Nitrate Nitrite (mg/l)[3]	90	0.004	1.1	0.10	0.18	0.04
Nitrogen, Total as N[3], estimated (mg/l)	88	0.06	3	1.81	0.46	1.76
Nitrogen Kjeldahl as N (mg/l)	88	0.06	3.2	1.71	0.40	1.70
pH (su)	92	6.4	8.8	7.5	0.4	7.3
P in dissolved Orthophosphate (mg/l)	55	0.004	0.260	0.046	0.049	0.035
Water Temperature (Celsius)	90	13.7	31.9	25.8	4.9	27.1
Total Organic Carbon (mg/l)	76	16	32	22	3	21
Total Suspended Solids (TSS;mg/l)	24	3.0	45	10.2	8.5	7.4
Turbidity (NTU)	71	2.1	26	5.8	3.8	4.6

1. Obs= number of observations; Max= maximum value; Min= mininum value; Mean= average value; StDev= standard deviation; Median= median value.
2. Some values contributing to these statistics were below the practical quantification or reporting limit; in those instances the value was left as the reported limit. Please see original data for any associated remark codes.
3. Two outliers of nitrate nitrite were removed from the dataset to calculate these statistics. The values were 280 mg/l and 320 mg/l, both measured on 11/4/2003. These values are substantially greater than the next highest maximum value of 1.1 mg/l nitrate-nitrite. Removal of these points will also affect the statistics for total nitrogen.

Nutrients

Excessive nutrients in a waterbody can lead to overgrowth of algae and other aquatic plants such as phytoplankton, periphyton and macrophytes. This process can deplete oxygen in the water, adversely affecting aquatic life and potentially restricting recreational uses such as fishing and boating.

While the State of Florida does not have numeric criteria for nutrients, a narrative criterion exists as described in the Water Quality Standards section of this report. Chlorophyll and dissolved oxygen are used to indicate whether nutrients are present in excessive amounts. For Class III marine waters, the dissolved oxygen should not be less than 5.0 mg/l in a 24-hour period, and should never be less than 4.0 mg/l. For Class III fresh waters, the dissolved oxygen should not be less than 5.0 mg/l.

Chlorophyll is the green pigment in plants that allows them to create energy from light. In a water sample, chlorophyll is indicative of the presence of algae, and chlorophyll-a is simply a measure of the active portion of total chlorophyll. In general, the corrected chlorophyll-a measurements for Billy Creek are low, but there are some values that appear elevated (Figure 10). The corrected chlorophyll-a measurements for WBID 3240J range from 1.0 to 33.5 µg/l, with a mean value of 3.9 µg/l and a median of 2.0 µg/l. Total ammonia concentrations as high as 1.55 mg/l were measured (Table 5).

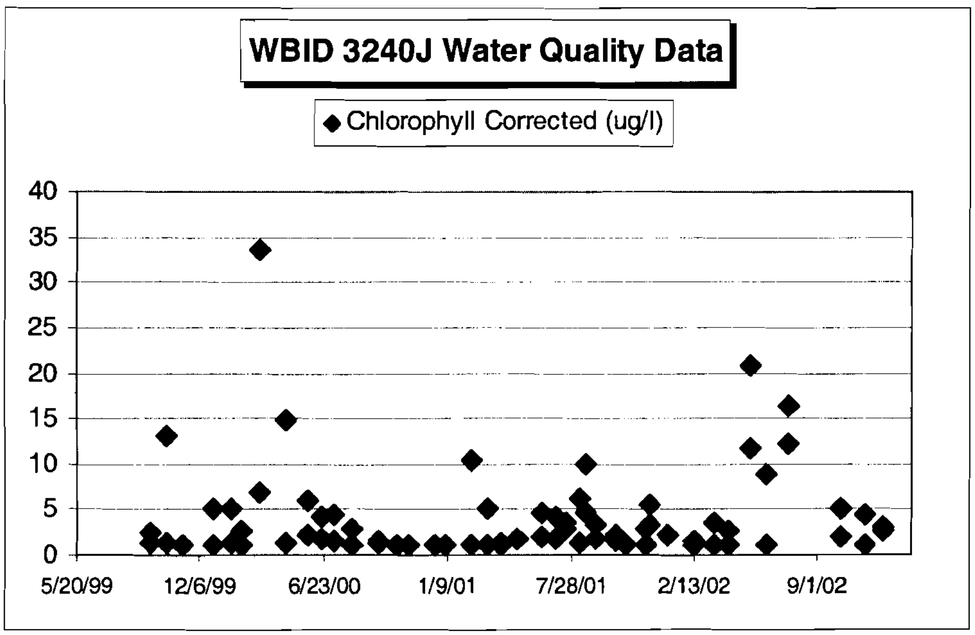

Figure 10. Chlorophyll Measurements for Billy Creek (WBID 3240J).

There is high variability in the chlorophyll-a concentrations measured in Ninemile Canal, WBID 3237D (Table 6). Chlorophyll has been measured as low as 1 µg/l, and as high as 310 µg/l. Although the average concentration is 15.8 µg/l, and the median is very low (3.5 µg/l), there are several elevated measurements (Figure 11). In addition, nitrogen concentrations, both as total ammonia and nitrate nitrite show some very high values (Table 6).

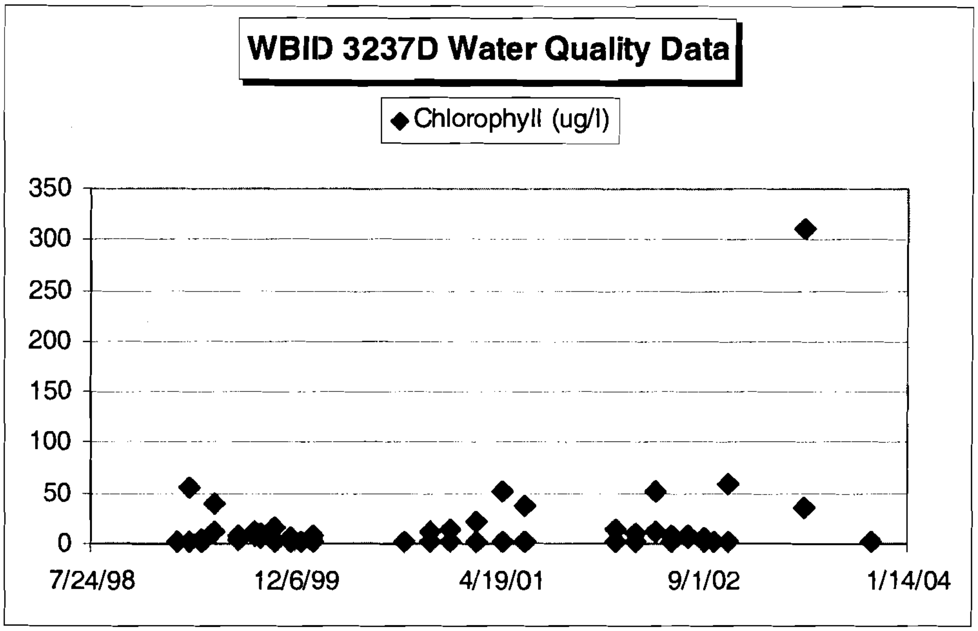

Figure 11. Chlorophyll Measurements for Ninemile Canal (WBID 3237D).

In Daughtrey Creek, WBID 3240F, chlorophyll also shows a significant deviation, ranging from 1 µg/l to 150 µg/l. Despite this, the average is only 8.8 µg/l (Figure 12 and Table 7).

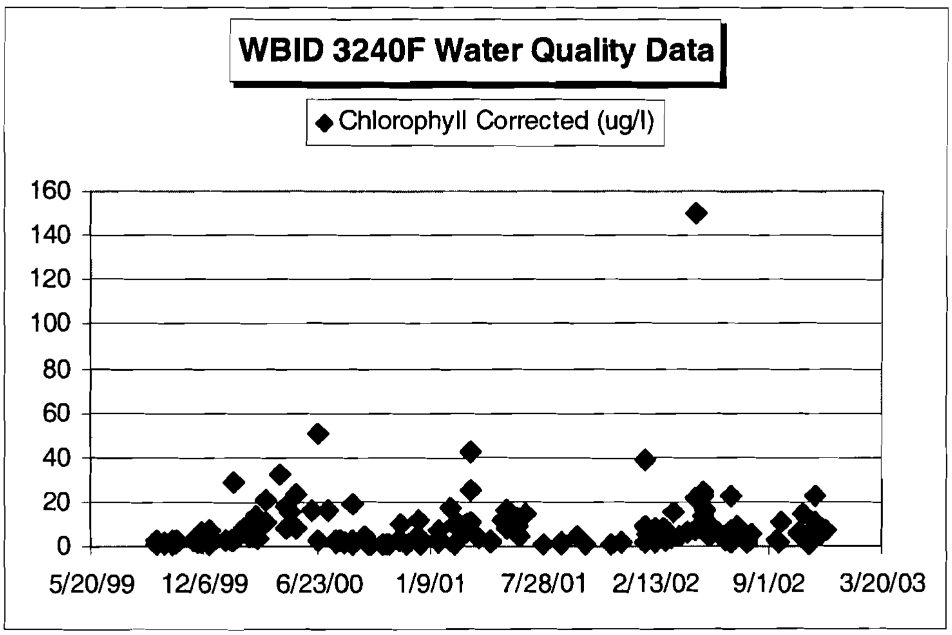

Figure 12. Chlorophyll Measurements for Daughtrey Creek (WBID 3240F).

Many of the chlorophyll-a data for Lake Hicpochee (WBID 3237C) appear elevated (Figure 13). Chlorophyll concentrations range from 1.0 to 389 µg/l, with a mean of 27 µg/l and a median of 18.5 µg/l. There are also many high nitrate-nitrite and ammonia values in the WBID (Table 8).

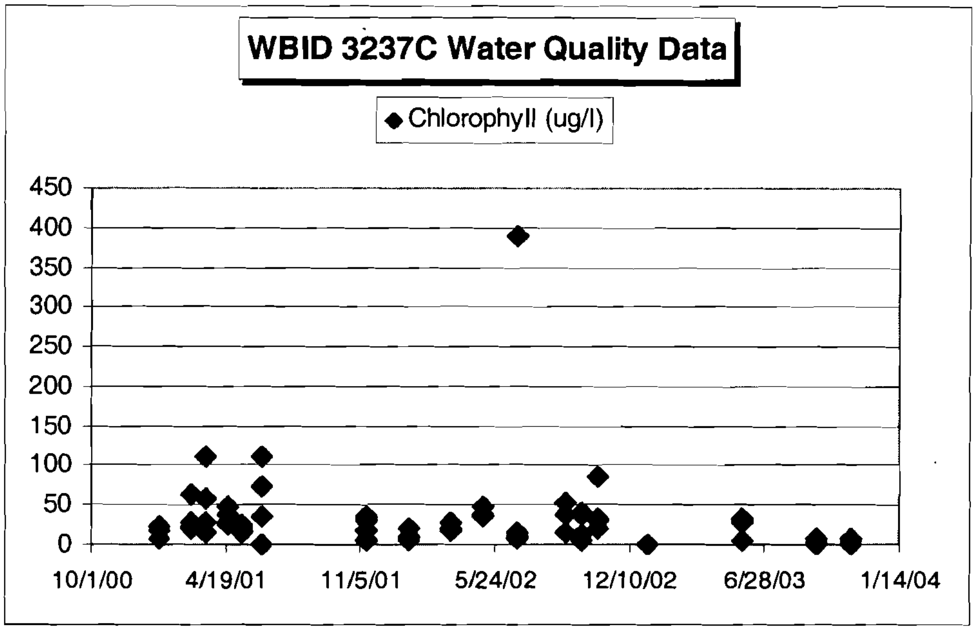

Figure 13. Chlorophyll Measurements for Lake Hicpochee (WBID 3237C).

Dissolved Oxygen and Biochemical Oxygen Demand

There are several factors that affect the concentration of dissolved oxygen (D.O.) in a waterbody. Oxygen can be introduced by wind, diffusion, photosynthesis, and additions of higher D.O. water (e.g. from tributaries). Dissolved oxygen concentrations are lowered by processes that use up oxygen from the water, such as respiration and decomposition, and by additions of water with lower D.O. (e.g. groundwater). Natural dissolved oxygen levels are a function of water temperature, water depth and velocity, and relative contributions of groundwater. Warm water holds less oxygen than cool water, and slower-flowing, less turbulent water has less diffusion of atmospheric oxygen into it. Because it is not in contact with air, groundwater naturally has lower concentrations of oxygen dissolved in it. Decomposition of organic matter, such as dead plants and animals, also uses up dissolved oxygen. Biochemical oxygen demand (BOD) is a measure of the amount of oxygen used by bacteria as they stabilize organic matter.

D.O. levels naturally fluctuate over the course of a day. During the daylight, submerged aquatic plants take up carbon dioxide and produce oxygen as by-products of photosynthesis. At night, respiration may consume dissolved oxygen from the water. Since carbon dioxide in solution has a slight acidifying effect, photosynthesis also affects pH as carbon dioxide is taken up from water and converted to simple organic compounds. The more plants and algae photosynthesize, the less acidic the water will become (i.e. the water will have higher pH).

The available D.O. data indicate that the dissolved oxygen concentration in Billy Creek is frequently below the Class III Marine Water Quality Criterion of 4 mg/L (Figure 14). Dissolved oxygen values measured between January 1997 and December 2002 range from 0.5 to 8.0 mg/l, with an average of 3.9 mg/l and a median of 3.8 mg/l. Biochemical oxygen demand (BOD) is high enough to suppress D.O. levels (see Table 5).

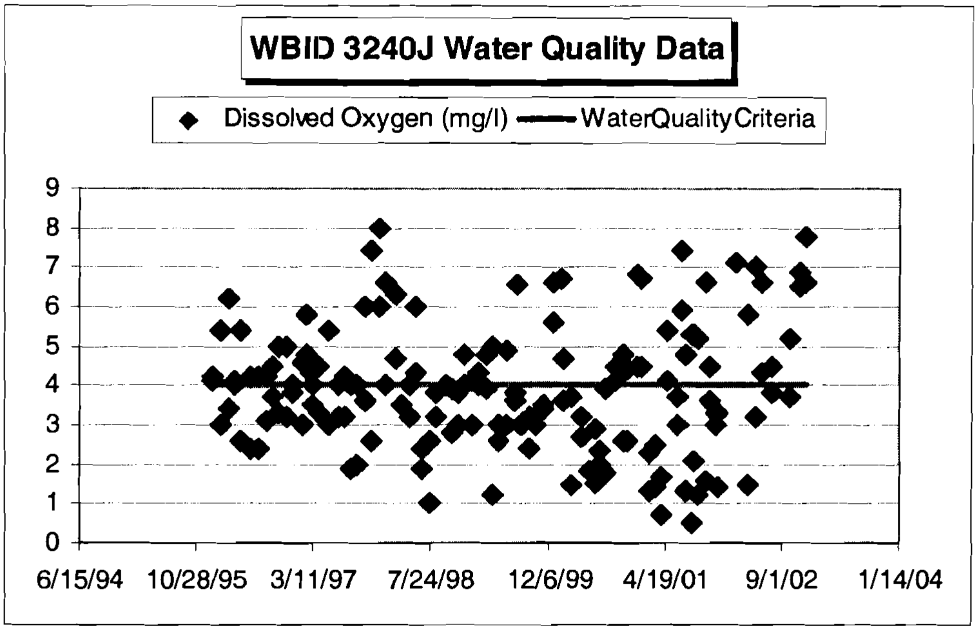

Figure 14. Dissolved Oxygen Measurements in Billy Creek, WBID 3240J.

In Ninemile Canal, D.O. is below the Class III Freshwater Criterion of 5 mg/l the majority of time (Figure 15). The D.O. concentrations range from 0.1 to 7 mg/l, but average only 1.8 mg/l (Table 6). Ninemile Canal is also 303(d)-listed for biochemical oxygen demand (BOD). The BOD dataset for Ninemile Canal is limited. BOD was measured as high as 5.7 mg/l, indicating that its contribution to suppression of D.O. in the canal is potentially significant (Figure 16). With one outlier removed, the correlation between BOD and D.O. is further supported by Figure 17.

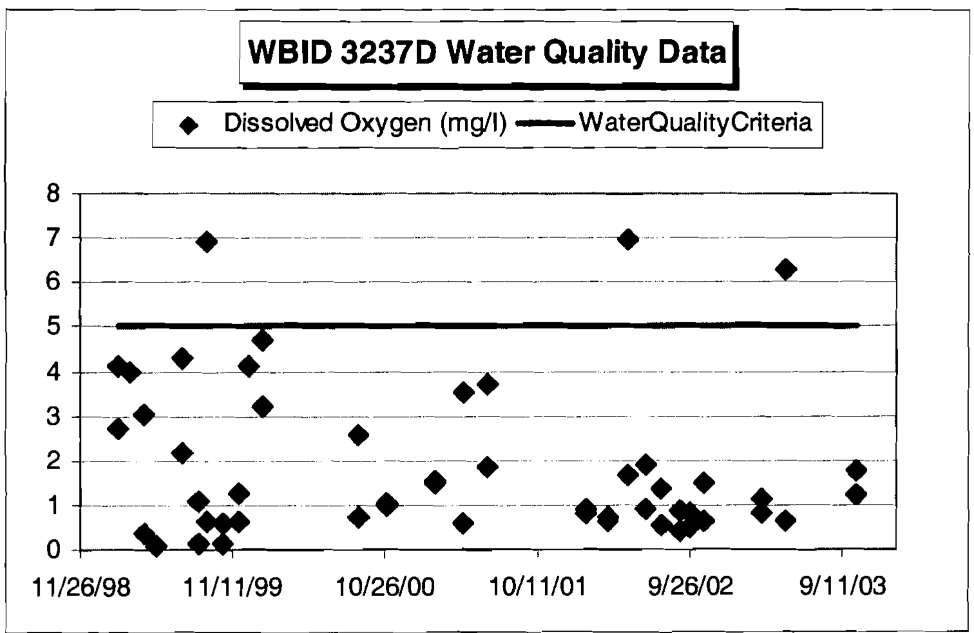

Figure 15. Dissolved Oxygen Measurements in Ninemile Canal, WBID 3237D.

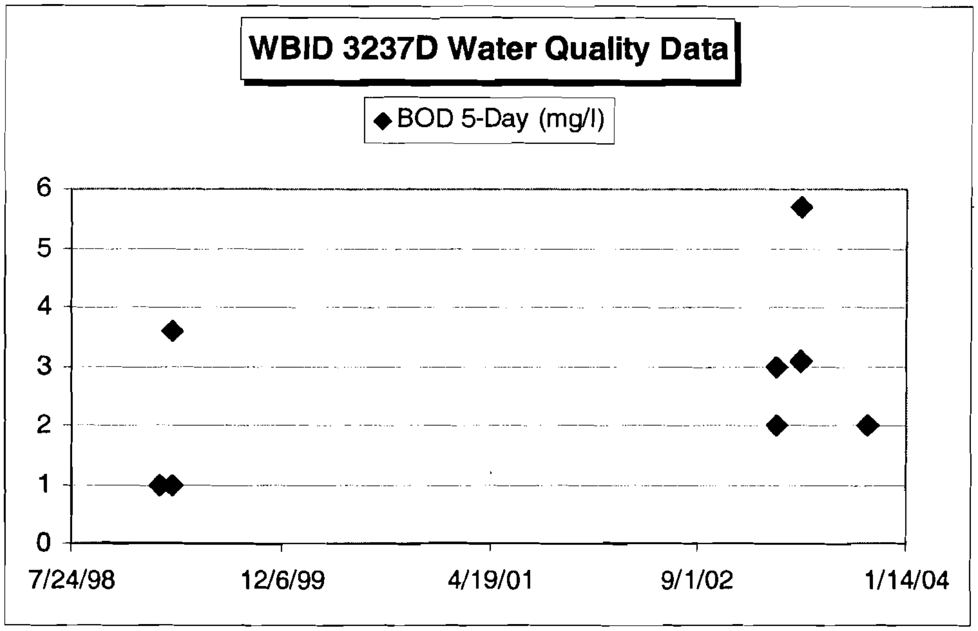

Figure 16. BOD concentrations in Ninemile Canal, WBID 3237D.

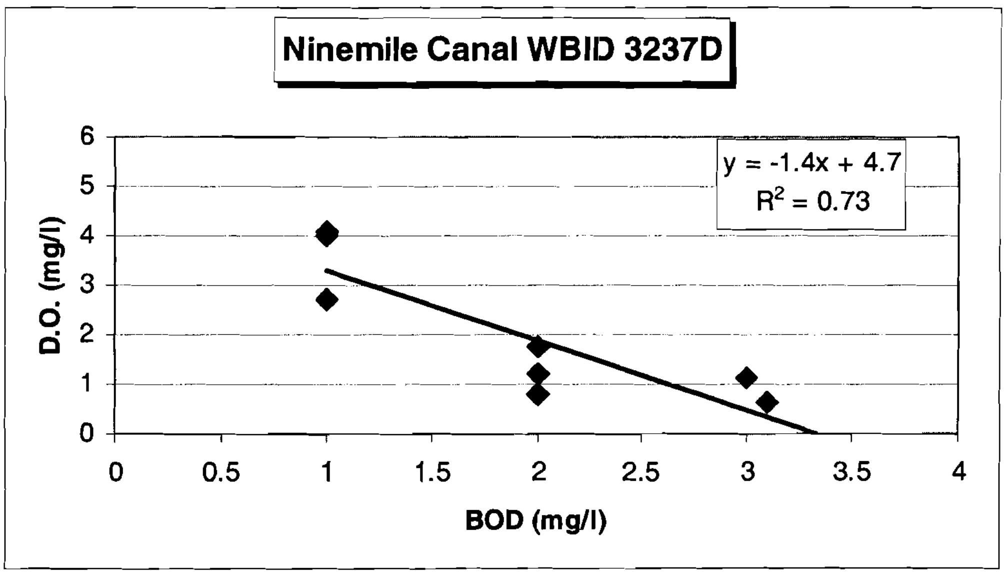

Figure 17. Relationship between D.O. and BOD in WBID 3237D.

D.O. data for Daughtrey Creek show many excursions below the Class III Freshwater Criterion of 5 mg/l. D.O. concentrations measured between January 1997 and December 2003 range from 0.1 mg/l to 8.3 mg/l, and average 3.9 mg/l (Figure 18). Although average BOD concentrations are relatively low, there are many values that are high enough to be of concern (Table 7).

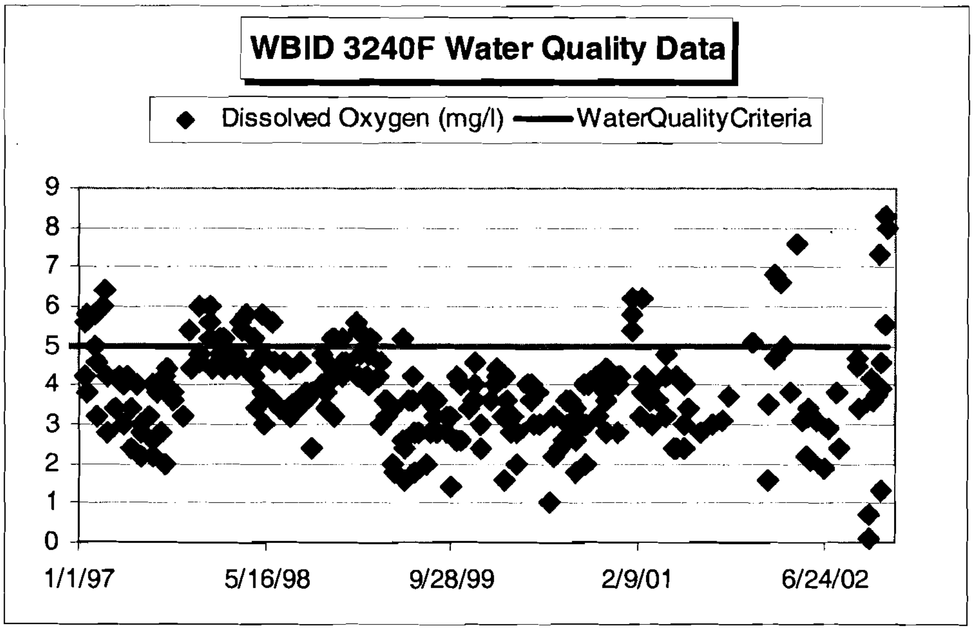

Figure 18. Dissolved Oxygen Measurements in Daughtrey Creek, WBID 3240F.

Dissolved oxygen (D.O.) concentrations in Lake Hicpochee are frequently below the Class III Freshwater Water Quality Criterion of 5 mg/l (Figure 19). The data show an almost 12 mg/l range in concentrations. Dissolved oxygen measurements made between January 2001 and June 2004 ranged from 0.9 to 12.8 mg/l, with an average of 6.0 mg/l and a median of 5.9 mg/l. The limited biochemical oxygen demand data suggest that BOD is sometimes high enough to suppress D.O. levels (see Table 8).

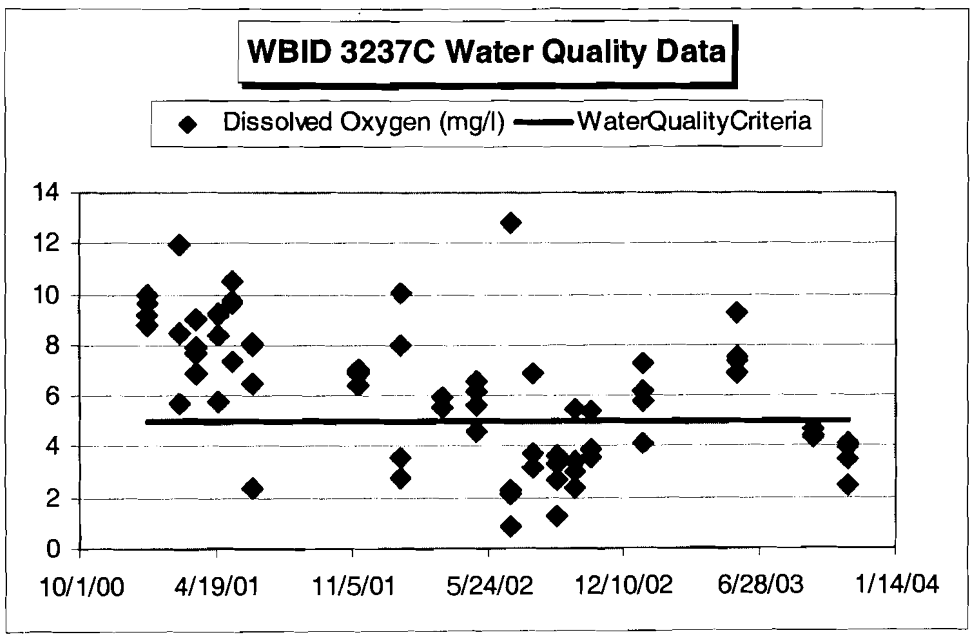

Figure 19. Dissolved Oxygen Measurements in Lake Hicpochee, WBID 3237C.

A positive correlation between D.O. and pH in Lake Hicpochee suggests that the fluctuations in D.O. are related to photosynthesis (Figure 20). As submerged plants photosynthesize, they take up carbon dioxide from the water, raising its pH, and they produce oxygen, increasing the water's D.O. concentrations.

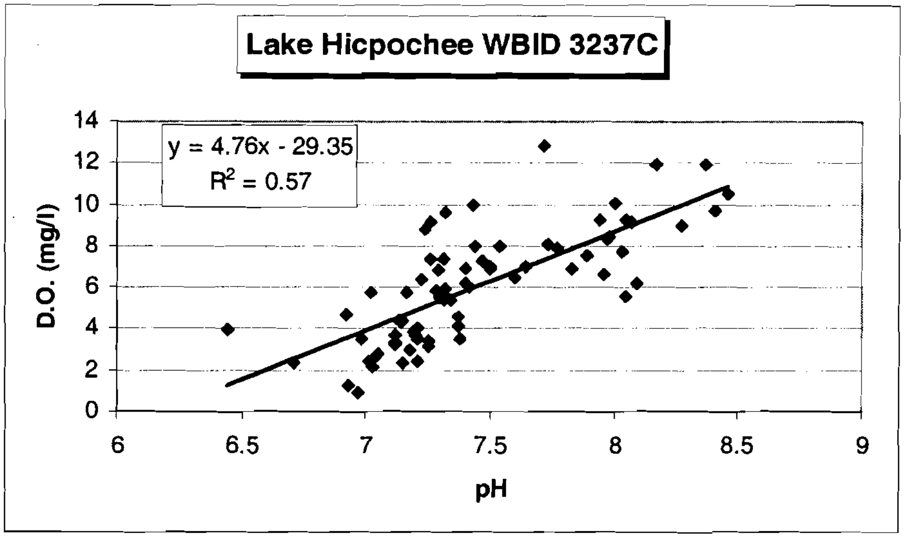

Figure 20. Relationship between pH and D.O. in Lake Hicpochee WBID 3237C.

When water quality is analyzed by station, Billy Creek at Ortiz Avenue, tends to show somewhat poorer water quality than the Palmetto Avenue station, which is further downstream (Table 9). Although the Ortiz Avenue station has about the same water temperature, and lower chlorophyll concentrations, its median concentrations of ammonia nitrogen, BOD, and fecal coliforms are much higher. This suggests that leaky sewers or septic systems could be the cause. Given the greater range in D.O. values, and higher chlorophyll concentrations at the downstream Palmetto Avenue station, it appears that there are more algal blooms in that area.

Table 9. Comparison of the Palmetto and Ortiz Avenue stations on Billy Creek.

Parameter	Station	Obs	Min	Max	Mean	StDev	Median
Chlorophyll A, corrected (µg/l)	Palmetto	41	1	33.5	4.6	6.3	2.1
	Ortiz	40	1	16.3	3.3	3.4	1.7
Dissolved Oxygen (mg/l)	Palmetto	70	0.5	8.0	3.9	1.8	4.0
	Ortiz	70	1.2	6.8	3.8	1.5	3.6
Water temperature (Celsius)	Palmetto	70	11.3	30.3	23.8	4.6	24.5
	Ortiz	70	10.4	31.0	23.3	4.7	24.0
BOD, carbonaceous 5-day (mg/l)	Palmetto	73	1	4.1	1.7	0.8	1.5
	Ortiz	72	1	8	3.1	1.6	2.8
Nitrogen Ammonia as N (mg/l)	Palmetto	73	0.012	0.545	0.078	0.105	0.024
	Ortiz	72	0.012	1.549	0.382	0.426	0.145
Fecal Coliforms (/100ml)	Palmetto	73	10	3010	419	636	180
	Ortiz	72	10	2780	670	670	360

1. Some values contributing to these statistics were below the practical quantification or reporting limit; in those instances the value was left as the reported limit.
2. Obs= number of observations; Max= maximum value; Min= mininum value; Mean= average value; StDev= standard deviation; Median= median value.

Summary of Data Assessments

As discussed above, only data collected in the Group 3 listing cycle, from 1997 to present, are included in the figures and the table of summary statistics. The original data are included in the Administrative Record for this report, and are also available upon request. Explanations of data remark codes are provided in Appendix A.

Based on the water quality information discussed above, TMDLs for D.O./BOD are being established for WBIDs 3240J, 3240F, and 3237D, and for nutrients in WBIDs 3237D and 3237C.

5.2 Source Assessment

An important part of the TMDL analysis is the identification of source categories, source subcategories, or individual sources of pollutants in the watershed and the amount of loading contributed by each of these sources. Sources are broadly classified as either point or non-point sources. Nutrients enter surface waters from both point and non-point sources.

A point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Point source discharges of industrial wastewater and treated sanitary wastewater must be authorized by National Pollutant Discharge Elimination System (NPDES) permits. NPDES permitted facilities, including certain urban stormwater discharges such as municipal separate stormwater systems (MS4 areas), certain industrial facilities, and construction sites over one acre, are storm-water driven sources considered "point sources" in this report.

Non-point sources of pollution are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These include nutrient runoff of agricultural fields, golf courses, and lawns, septic tanks, and residential developments outside of MS4 areas. These sources generally, but not always, involve accumulation of nutrients on land surfaces and wash off as a result of storm events.

5.2.1 Point Sources

WBIDs 3237C (Lake Hicopochee), 3240F (Daughtrey Creek) and 3237D (Ninemile Canal) are not currently affected by NPDES facilities within or upstream of their WBIDs. There are no facilities currently discharging directly to surface water in WBID 3240J or any of Billy Creek's upstream tributaries. The Fort Myers Central WWTP (FL0021261) is a major facility designed to discharge up to 11 MGD. Although the WWTP is physically located within WBID 3240J, and discharges pollutants of concern for D.O. impairment (especially B.O.D. and nutrients), its discharge is piped to the Caloosahatchee River estuary (WBID 3240B). Since Billy Creek is tidally-influenced, and this outfall location is just upstream of the junction with Billy Creek, the effect of this facility was included in the analysis for WBID 3240J (Billy Creek). However, because the outfall location is located outside of the Billy Creek WBID, no WLA is provided for it in the TMDL for WBID 3240J. The two WBIDs of the Caloosahatchee River Estuary nearest this outfall location, WBID 3240B (above Billy Creek) and WBID 3240A (below Billy Creek), are both verified as impaired for D.O. They have been assigned a medium priority, and are scheduled for TMDL development in 2009. Summary data for the Fort Myers AWWTF (permit FL0021261) are provided in Table 10 and Table 11. The permit for The Fort Myers WWTP acknowledges that FDEP may revise the permit and apply more stringent limitations at such time as a TMDL for the Caloosahatchee River Estuary is established.

Table 10. Statistics for Constituent Concentrations at FL0021261, 1995-2004.

Statistic	BOD5 (mg/L)	TP (mgP/L)	Daily Max PO4 (mgP/L)	TNH3 (mgN/L)	TN (mgN/L)
Max	5.4	0.190	NA	NA	4.300
90th	4.0	0.120	NA	NA	2.794
50th	2.6	0.090	NA	NA	1.750
10th	1.7	0.040	NA	NA	1.258
Min	1.4	0.030	NA	NA	1.110
Avg	2.8	0.087	NA	NA	1.986
Count	122	57	NA	NA	57

Table 11. Statistics for Mass and Volume Rates at FL0021261, 1995-2004.

Statistic	BOD5 (lb/d)	TP (lb/d)	Daily Max PO4 (lb/d)	TNH3 (lb/d)	TN (lb/d)	Flow (mgd)
Max	274.9	12.3	NA	NA	222.5	12.290
90th	213.9	7.0	NA	NA	138.9	8.950
50th	134.4	4.3	NA	NA	92.8	6.070
10th	94.9	2.3	NA	NA	67.8	4.940
Min	67.8	1.7	NA	NA	55.7	4.370
Avg	147.7	4.6	NA	NA	102.0	6.560
Count	121	57	NA	NA	57	121

A wasteload allocation (WLA) is only given to NPDES facilities discharging to surface waters and to permitted Municipal Separate Storm Sewer Systems (MS4s). It should be noted that wastewater facilities permits authorize a discharge only if the applicant provides reasonable assurance that the discharge will not cause or contribute to violations of the water quality criteria.

Municipal Separate Storm Sewer Systems (MS4s) may also discharge nutrients to waterbodies in response to storm events. Large and medium MS4s serving populations greater than 100,000 people are required to obtain a NPDES storm water permit under the Phase I storm water regulations. After March 2003, small MS4s serving urbanized areas are required to obtain a permit under the Phase II storm water regulations. An urbanized area is defined as an entity with a residential population of at least 50,000 people and an overall population density of 1,000 people per square mile. The Phase I MS4 permit #:FL000035, which covers Lee County, the City of Cape Coral, and the City of Fort Myers, may affect WBID 3240J (Billy Creek). Stormwater inputs have been cited as a reason for water quality problems in Billy Creek (FDEP, 2003).

5.2.2 Non-point Sources

Nonpoint sources that ultimately contribute to depletion of in-stream dissolved oxygen include sources of nutrients such as animal waste, waste-lagoon sludge, fertilizer application to agricultural fields, lawns, and golf courses, and malfunctioning onsite sewage treatment and disposal systems or septic tank systems.

In the eastern Caloosahatchee Basin, agriculture is the dominant activity, comprising over 80% of WBID 3237D (Ninemile Canal), and most of the area of WBID 3237C (Lake Hicpochee) that is not taken up by water or wetlands. Lake Hicpochee receives agricultural drainage from the surrounding areas, including in flows from Lake Okeechobee. The western portion of the basin is more developed. Daughtrey Creek's watershed (WBID 3240F) is a patchwork of natural, agricultural, and residential uses. The major landuses in WBID 3240J (Billy Creek) are high and medium density residential and commercial/industrial, with lesser amounts of agriculture (Table 2). Billy Creek receives stormwater from much of East Fort Myers, and many of the water quality problems in the area are linked to the urban and suburban landuses. The landcovers for the impaired WBIDs were provided in Table 2.

5.2.2.1 Wildlife

Wildlife deposit bacteria deposit their feces onto land surfaces where it can be transported during storm events to nearby streams. Generally, the nutrient load from wildlife is assumed to be background, as the contribution from this source is small relative to the load from urban and agricultural areas in most watersheds. In addition, any strategy employed to control this source would probably have a negligible impact on obtaining water quality standards.

5.2.2.2 Agricultural Uses

Agricultural activities, including runoff of fertilizers and animal wastes from pasture and cropland, can impact water quality. Farm data from the 2002 Census of Agriculture for Lee, Charlotte, Hendry and Glades Counties are listed in Table 12. The data show that farming is more predominant in the counties that comprise the eastern portion of the Caloosahatchee Basin. Between 1997 and 2002, Glades County experienced an 8% increase in farmland, while Lee, Hendry, and Glades counties experienced declines in farmland of 6%, 9%, and 34%, respectively.

The Florida Department of Agriculture and Consumer Services (FDACS), Office of Agricultural Water Policy developed a manual outlining best management practice for cow/calf operations (FDACS, 1999). In this report the authors state "implementation of the practices described in this manual provides a good argument that you have made reasonable efforts to reduce pollutants from your ranch by the maximum practicable amount". The manual acknowledges "after implementation of these BMPs it may be necessary to add more stringent guidelines for site specific areas that continue to exceed water quality standards".

Table 12. Farmland and Livestock Inventory for Counties in the Caloosahatchee Basin.

Livestock (inventory)	Charlotte	Glades	Hendry	Lee
Number of farms	284	231	456	643
Land in farms (acres)	191,529	407,950	552,352	126,484
Ave size of farm (acres)	674	1,766	1,211	197
Total cropland (acres)	41,928	73,043	296,006	36,422

source: NASS, 2002

5.2.2.3 Onsite Sewerage Treatment and Disposal Systems (Septic Tanks)

Onsite sewage treatment and disposal systems (OSTDs) including septic tanks are commonly used where providing central sewer is not cost effective or practical. When properly sited, designed, constructed, maintained, and operated, OSTDs are a safe means of disposing of domestic waste. The effluent from a well-functioning OSTD is comparable to secondarily treated wastewater from a sewage treatment plant. When not functioning properly, OSTDs can be a source of nutrients (nitrogen and phosphorus), BOD, pathogens, and other pollutants to both ground and surface water.

The State of Florida Department of Health (DOH) publishes statistics regarding septic tanks on a county basis (see: http://www.doh.state.fl.us/environment/OSTDS/statistics/ostdsstatistics.htm). Table 13 summarizes the number of septic systems installed since the 1970 census and the total number of repair permits issued between 1997 and 2004.

Table 13. Estimates of Septic Tanks and Repair Permits for Lee County (FDOH, 2005).

County	Number of Septic Tanks (2004)	Number of Repair Permits Issued (1997 – 2004)
Lee	98,938	1,969
Charlotte	39,234	713
Glades	4,769	173
Hendry	9,307	283

The data in Table 13 do not account for septic tanks removed from service. The higher incidence of residential development in Lee and Charlotte counties, which encompass Billy Creek and Daughtrey Creek, is apparent from the greater number of septic tanks.

5.2.2.4 Urban Development

Nutrient loading from urban areas is attributable to multiple sources including storm water runoff, leaks and overflows from sanitary sewer systems, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Urban development is an important nonpoint source in WBID 3240J (Billy Creek), and to a lesser extent in WBID 3240F (Daughtrey Creek).

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as outlined in Chapter 403 Florida Statutes (F.S.), was established as a technology-based program that relies upon the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, F.A.C.

Florida's stormwater program is unique in having a performance standard for older stormwater systems that were built before the implementation of the Stormwater Rule in 1982. This rule states: "the pollutant loading from older stormwater management systems shall be reduced as needed to restore or maintain the beneficial uses of water" (Section 62-4-.432 (5)(c), F.A.C.).
Nonstructural and structural BMPs are an integral part of the State's stormwater programs. Nonstructural BMPs, often referred to as "source controls", are those that can be used to prevent the generation of NPS pollutants or to limit their transport off-site. Typical nonstructural BMPs include public education, land use management, preservation of wetlands and floodplains, and minimizing impervious surfaces. Technology-based structural BMPs are used to mitigate the increased stormwater peak discharge rate, volume, and pollutant loadings that accompany urbanization.

5.3 Analytical Approaches for TMDLs

In the following section, the approaches that were used to develop TMDLs in the Caloosahatchee River Basin are described. First, Billy and Daughtrey Creek are discussed together, since the same approach was used for both. Then, the analysis for Ninemile Canal is explained, followed by Lake Hicpochee.

5.3.1 Billy Creek and Daughtrey Creek

Billy Creek (WBID 3240J) and Daughtrey Creek (WBID 3240F) were both listed for impairment due to low dissolved oxygen. Since dissolved oxygen is not a pollutant, the TMDLs should allocate limitations for a pollutant that causes low dissolved oxygen. For both of these streams, the causative pollutant targeted for the TMDL is biochemical oxygen demand (BOD). BOD is a measure of the amount of oxygen used by bacteria as they stabilize organic matter. Carbonaceous Biochemical Oxygen Demand (CBOD) is the carbonaceous portion of that demand that occurs in the first stage of decomposition as organic matter is converted to carbon dioxide.

Both Daughtrey Creek and Billy Creek are located in the western portion of the Caloosahatchee River Basin, and both follow a similar methodology for TMDL development. Four models were used in the effort to quantify the effects of CBOD on DO concentrations in Billy and Daughtrey Creeks: the Grid Based Mercury Model (GBMM), the Pollutant Loading Spreadsheet Model (PLSM), the EPA Water Quality Simulation Analysis Program (WASP7), and a spreadsheet SOD model developed by Quantitative Environmental Analysis (QEA) and modified by Dr. James Martin of Mississippi State University. The Pollutant Load Screening Model (PLSM) was used to calculate the concentration and load of CBOD entering each creek from nonpoint sources in the watershed. The U.S. EPA Water Quality Analysis Simulation Program version 7 (WASP7) was applied as the instream water quality model (Wool et. al., 2001). The eutrophication component of WASP was used to simulate the complex nutrient transport and cycling in the streams, as well as to determine the dissolved oxygen sag. The purpose of the modeling exercise was to determine what reductions in the BOD loads to each stream would have to occur in order to protect the designated use and achieve water quality standards in each waterbody.

<u>**Grid Based Mercury Model (GBMM)**</u>

The Grid Based Mercury Model (GBMM) is a GIS environment extension that aids in defining the segmentation and boundary conditions for the WASP7 model input file. The GBMM extension utilizes the National Hydrography Dataset (NHD) and the National Elevation Dataset (NED) along with various other coverages, including watershed boundary, weather data and soils. GBMM was used to predict inflows to the WASP model where there are no USGS gages. GBMM predicts runoff as a function of landuse (pervious/impervious area), slope, soil type, infiltration and evaporation. When the GBMM was executed, two ASCII files were produced for use in building the WASP7 application for Billy Creek. These same ASCII files were produced for Daughtrey Creek by running PLSM. One of the files is flow.txt, which contains two important pieces of information: 1) how the segments were connected to one another, and 2) a time series of flow for each individual segment drainage area. The other file is segment.txt, which contains the following information for each segment:

- Segment Name
- Segment Number
- Length (m)

- Width (m)
- Depth Multiplier
- Velocity Multiplier
- Slope (m/m)
- Mannings Roughness

There were a total of 25 segments for Billy Creek, and 5 segments for Daughtrey Creek. Schematics of the WASP7 model networks for Billy Creek and Daughtrey Creek are shown in Figure 21 and Figure 22, respectively. On Billy Creek, station 21FLEECOBILLGR60 (Billy Creek at Ortiz Avenue) is located at River Mile 3.45, which corresponds to Segment 9, and Station 21FLEECOBILLGR20 (Billy Creek at Palmetto Avenue) is located downstream at River Mile 1.54, in Segment 1. On Daughtrey Creek, station 21FLEECO20-9GR (Daughtrey Creek- SR78) is located at RM 1.86, which corresponds to segment 4, and station 21FLEECO20-29GR (Daughtrey Creek-Nalle Grade Bridge) is located at RM 5.59, in segment 1.

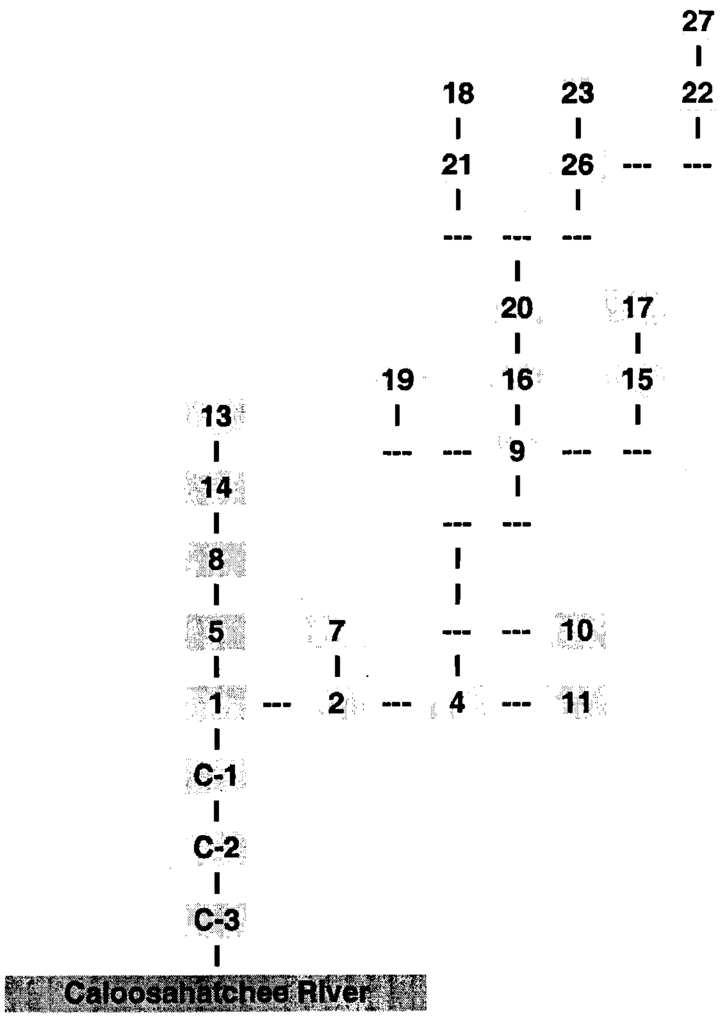

Figure 21. Schematic of Billy Creek Segments in WASP7 Model.

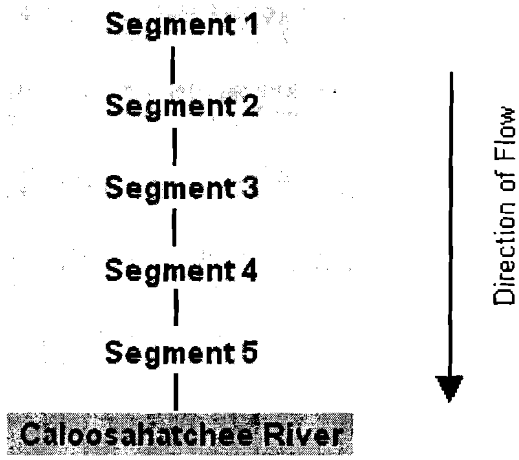

Figure 22. Schematic of Daughtrey Creek Segments in WASP7 Model.

Pollutant Loading Spreadsheet Model (PLSM)

PLASM utilizes a computer-driven geographic information system framework to calculate constituent loads as the product of water quality concentration associated with certain land use practices, and runoff water volume associated with those same practices. Additional details about PLSM may be found below, in the section describing the analytical approach used to develop the Ninemile Canal TMDLs.

PLSM models were developed to estimate BOD loads coming off the watersheds of Billy and Daughtrey Creeks. Time series of CBOD loads entering each creek from the nonpoint sources in their respective WBIDs were generated. PLSM calculated both the concentration and load of BOD5 for each of three seasons (Table 14), and for each of the segments in the WASP7 models. Season 1 extends from December to March, Season 2 from April to July, and Season 3 from August to November. BOD5 is a standard way to express biochemical oxygen demand. BOD5 characterizes the oxygen used up by decomposition after 5-days at 20 degrees Celsius.

Table 14. BOD loads obtained from PLSM for Billy and Daughtrey Creeks.

	Season 1			Season 2			Season 3		
WBID	**Conc. (mg/L)**	**Daily Load (lb/day)**	**Seasonal Load (lb/season)**	**Conc. (mg/L)**	**Daily Load (lb/day)**	**Seasonal Load (lb/season)**	**Conc. (mg/L)**	**Daily Load (lb/day)**	**Seasonal Load (lb/season)**
3240J	1.53	132.0	16238.4	1.50	196.4	23959.5	1.521	411.8	50241.2
3240F	1.36	189.1	23252.7	1.24	291.3	35541.5	1.41	604.2	73708.7

To determine the loading of BOD to each WASP segment, the load for the entire WBID was area-weighted to the segment drainage area. The units were then converted from (lb/d) to (kg/d) by dividing (lb/day) by 2.2046. The BOD5 estimates were converted to CBODu by using an f-ratio of 3.0. CBODu is the ultimate carbonaceous demand representing complete biochemical oxidation of organic matter. This procedure was done for each season. A time-series of CBODu load was then created for each segment and input into WASP7. Estimates for the existing loadings of CBODu to each segment in Billy Creek are provided in Table 15, and for Daughtrey Creek in Table 16.

Table 15. CBODu Loading for each WASP7 segment in Billy Creek.

Segment	Segment Drainage Area (m^2)	Area-Weight Factor	Season 1 Load (kg/day)	Season 2 Load (kg/day)	Season 3 Load (kg/day)
1	1904400	0.0360	6.476	9.633	20.201
2	1191600	0.0226	4.052	6.028	12.640
4	4296600	0.0813	14.611	21.735	45.576
5	321300	0.0061	1.093	1.625	3.408
7	531000	0.0101	1.806	2.686	5.633
8	1049400	0.0199	3.569	5.308	11.131
9	1446300	0.0274	4.918	7.316	15.341
10	138600	0.0026	0.471	0.701	1.470
11	1298700	0.0246	4.416	6.570	13.776
13	73800	0.0014	0.251	0.373	0.783
14	366300	0.0069	1.246	1.853	3.885
15	252000	0.0048	0.857	1.275	2.673
16	648000	0.0123	2.204	3.278	6.874
17	90000	0.0017	0.306	0.455	0.955
18	433800	0.0082	1.475	2.194	4.601
19	198900	0.0038	0.676	1.006	2.110
20	658800	0.0125	2.240	3.333	6.988
21	70200	0.0013	0.239	0.355	0.745
22	1314000	0.0249	4.468	6.647	13.938
23	400500	0.0076	1.362	2.026	4.248
26	43200	0.0008	0.147	0.219	0.458
27	12600	0.0002	0.043	0.064	0.134

Table 16. CBODu Loading for each WASP7 segment in Daughtrey Creek.

Segment	Segment Drainage Area (m^2)	Area-Weight Factor	Season 1 Load (kg/day)	Season 2 Load (kg/day)	Season 3 Load (kg/day)
1	1205100	0.0156	4.004	6.171	12.798
2	3203100	0.0414	10.643	16.402	34.015
3	2187000	0.0282	7.267	11.199	23.225
4	2752200	0.0355	9.145	14.093	29.227
5	2304900	0.0298	7.659	11.082	24.477

WASP7

WASP contains algorithms to simulate eutrophication processes with a basic Streeter-Phelps analysis. The model has a suite of options that allow the user to tailor the degree of complexity and constituent interactions for a given project. For these applications, WASP7 was set-up to simulate basic Streeter-Phelps processes to predict DO and CBOD1 (ultimate). A limited number of systems were selected to simplify the approach, yet still capture the importance of the dominant processes.

Constants were selected for the two systems (D.O. and CBOD) simulated in this application based on literature values (Table 17). Constants used to simulate DO are related to reaeration and a stoichiometric ratio; values for CBOD (ultimate) describe the decay rate and half saturation limit.

Table 17. Constants used in WASP7 models for simulating DO and CBOD1 (ultimate).

Parameter Simulated	Constant	Value
DO	Minimum Reaeration Rate (per day)	0.00005
	Theta—Reaeration Temperature Correction	1.0477
	Oxygen to Carbon Stoichiometric Ratio	2.67
CBOD1 (ultimate)	BOD (1) Decay Rate Constant @ 20^0 C (per day)	0.02
	BOD(1) Decay Rate Temperature Correction Coefficient	1.04
	BOD(1) Half Saturation Oxygen Limit (mg O/L)	0.5

The water quality data available to characterize Billy Creek were observed from the two stations previously noted: 21FLEECOBILLGR20 (RM 1.54) and 21FLEECOBILLGR60 (RM 3.45). The available dataset for Daughtrey Creek also offered only two locations for water quality data collected during the period of interest: 21FLEECO20-9GR (RM 1.86) and 21FLEECO20-29GR (RM 5.59). Since the locations of observations in the streams were limited, the time series of water temperature and dissolved oxygen from the two water quality locations in each stream were used to parameterize the condition of the water entering the WASP7 network. In the Billy Creek WASP model, station 21FLEECOBILLGR20 (Palmetto Ave.) was used for segments 1-8 and 10-14, and Station 21FLEECOBILLGR60 (Ortiz Ave.) was used for the remaining segments (9 and 15-27). In the Daughtrey Creek WASP model, station 21FLEECO20-29GR was used for segments 1-3 and station 21FLEECO20-9GR was used as the boundary input for segments 4 and 5.

Sediment oxygen demand (SOD) is a main component of both the Billy Creek and Daughtrey Creek WASP models. Sediment oxygen demand is the rate of oxygen consumption exerted by bottom sediment on overlying water. SOD data are not available in either WBID, so model parameters were based on literature values and estimates used in other modeling applications. During model set-up, SOD was set to an initial value of 1.0 g/(m^2/d). After the iterative calibration process, SOD was ultimately set to 3.0 g/(m^2/d).

In the Billy Creek model, dispersion is also a primary parameter. Generally speaking, dispersion occurs from the velocity gradients of a profile acting to smear a slug of constituent (Martin, 2002). The most downstream segment of the WASP7 model was developed to represent the main body of the Caloosahatchee River. In other words, it was assigned a large segment volume and a large dispersion coefficient of 10,000 m^2/s. Upstream, the dispersion was set to 30 m^2/s. The WASP7 was setup to allow dispersion between segments 1, 2, 4, 5, 7, 8, 9, 10 and 11 of the Billy Creek model (Figure 21).

One point source was considered during the Billy Creek modeling effort: The Ft Myers-Central STP (NPDES FL0021261). This source discharges its effluent to the Caloosahatchee River Estuary, near the mouth of Billy Creek. It was considered in the analysis because of the possibility that effluent from the point source may be pushed up into Billy Creek in the tidal cycle. As a conservative assumption, effluent form the point source was coded as input to the second most downstream segment of the WASP7 model, C-2.

WASP7 Calibration

Once model input forcings and parameters were developed, the model was simulated on an iterative basis to enable calibration. During the calibration process it was determined that the dominant parameter was the sediment oxygen demand (SOD). Therefore, the calibration of both models was performed by adjusting SOD until the simulated dissolved oxygen values were close to the measured values for the respective streams.

In Billy Creek, the model runs were compared to the observed data for the period of 1996-2002. The period 1998-1999 was selected as the critical period for the simulations since the rainfall for these two years was significantly lower than the annual average. The model's performance simulating D.O. was evaluated at the two locations corresponding to water quality stations (RM 1.54 in Segment 1 and RM 3.45 in Segment 9). Time series comparisons were developed for both segments, and are presented in Figure 23 through Figure **26**. The comparisons at river mile 3.45 are reasonable. Simulation comparisons at river mile 1.54 presented some discrepancy for 2001. However, considering the lack of model forcing information and assumptions, the model simulations are considered reasonable.

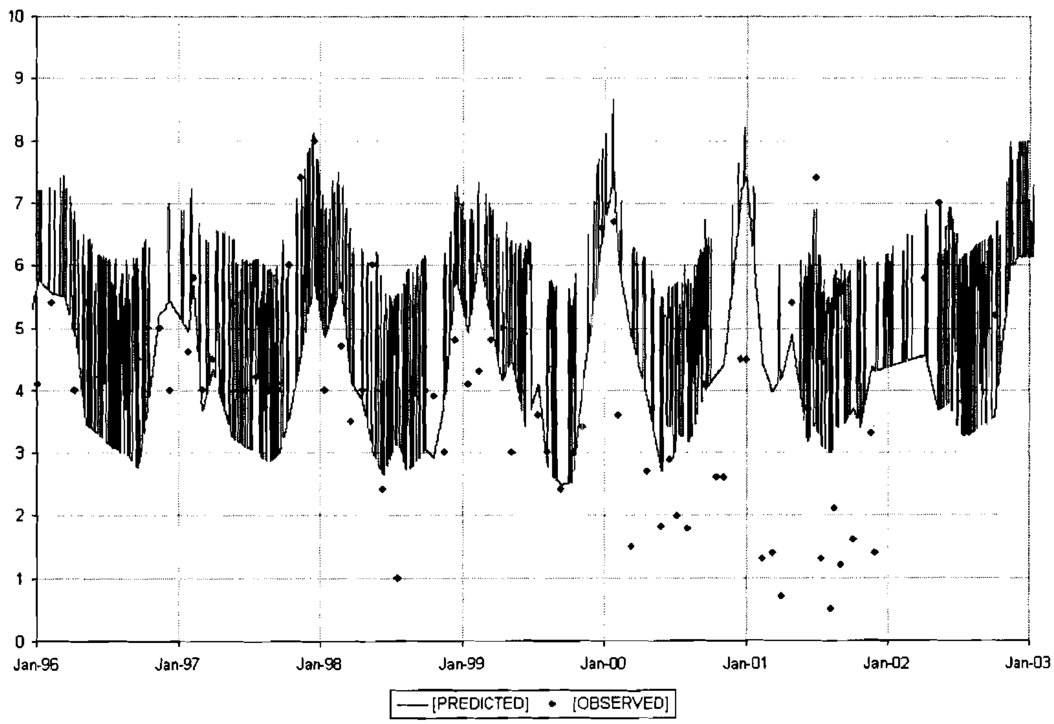

Figure 23. Segment 1, DO Calibration for Billy Creek (1996-2002).

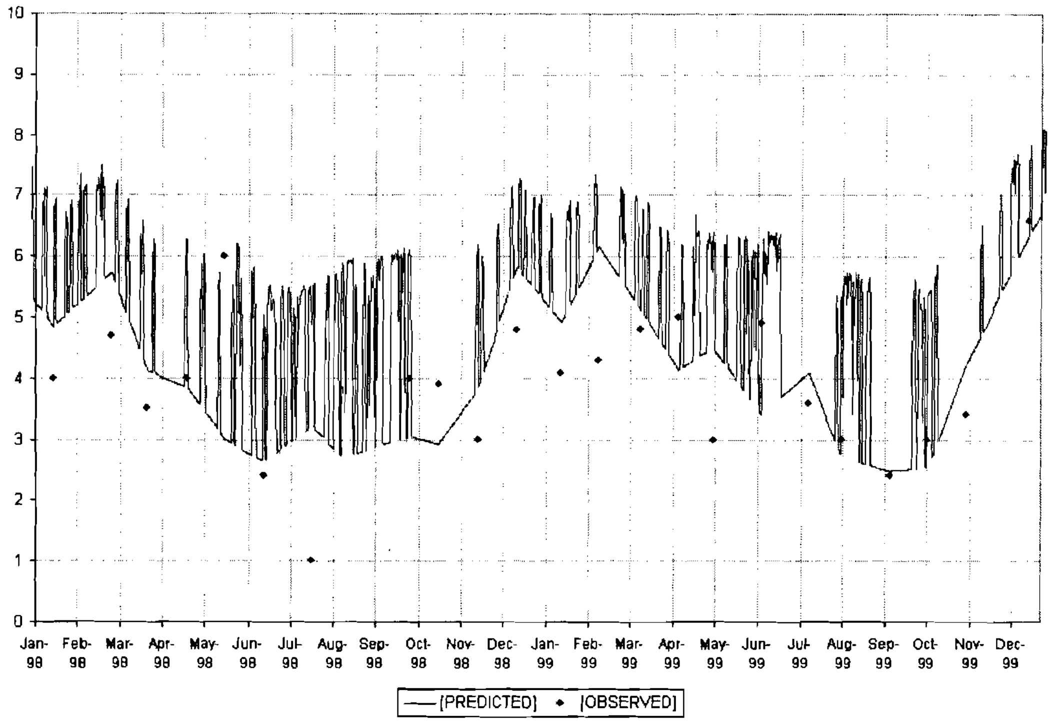

Figure 24. Segment 1, DO Calibration for Billy Creek (1998-1999).

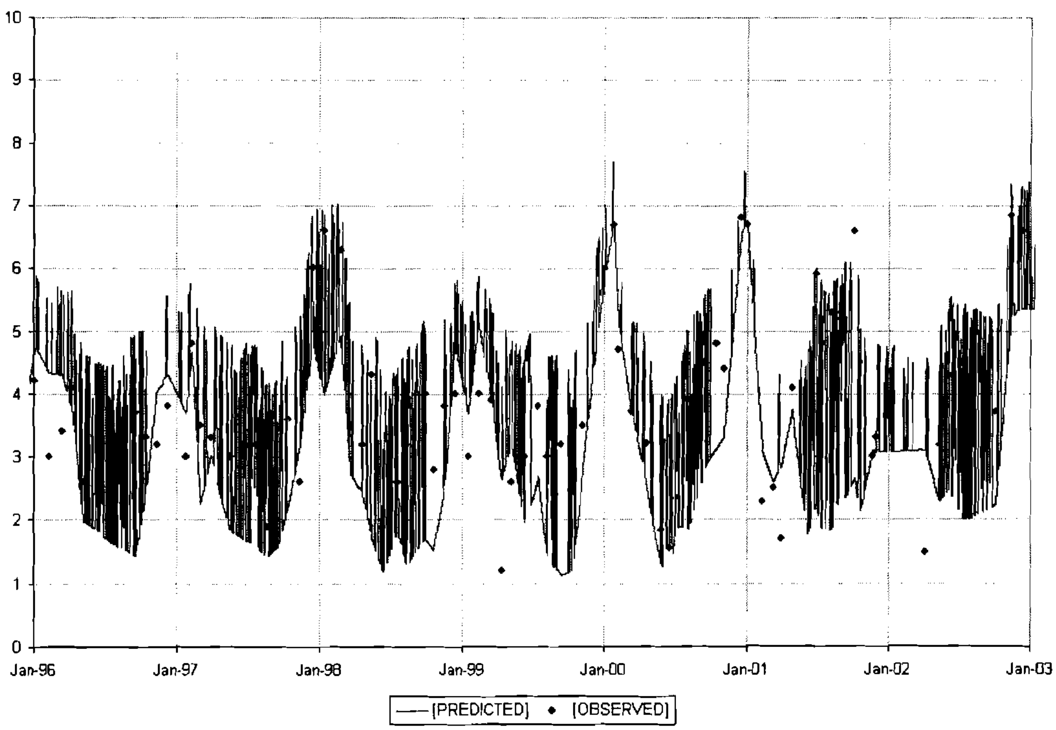

Figure 25. Segment 9, DO Calibration for Billy Creek (1996-2002).

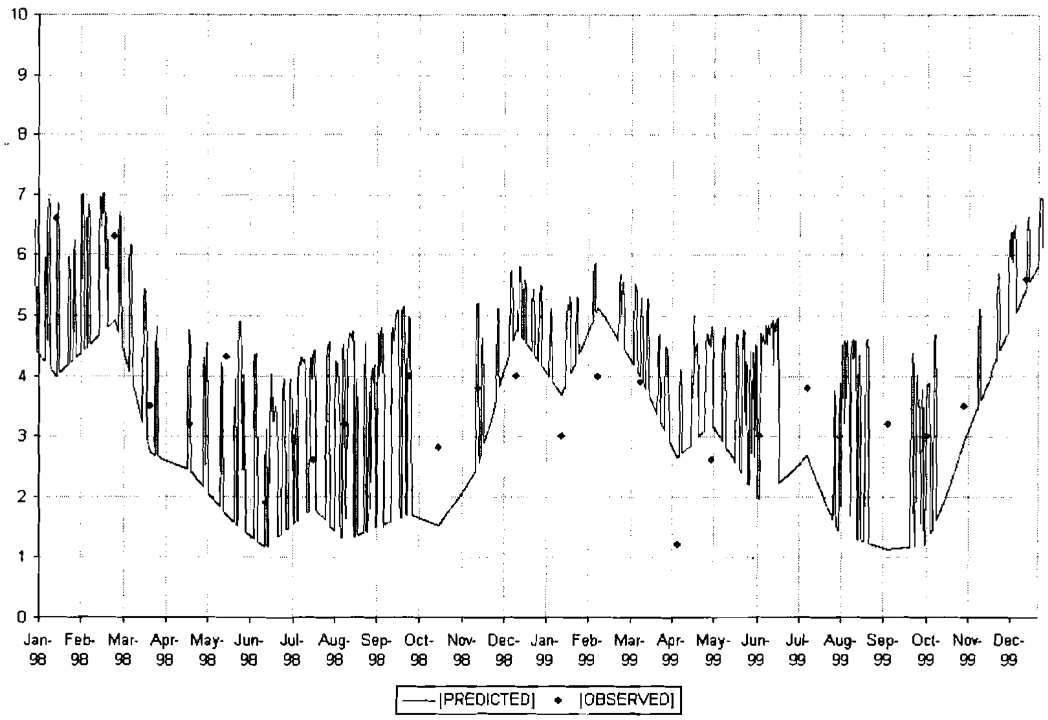

Figure 26. Segment 9, DO Calibration for Billy Creek (1998-1999).

In Daughtrey Creek, the model runs were compared to the observed data collected between 1996-2003. As with Billy Creek, 1998-1999 was selected as the critical period for the simulations due to the lower than average rainfall that occurred during those two years. Simulated model performance for dissolved oxygen was evaluated at two locations corresponding to the ambient water quality stations. Time series comparisons were developed for Segment 1 (RM 5.59) and Segment 4 (RM 1.86). These results are presented in Figure 27 through Figure 30. There is some variation of simulated versus observed data, especially in late 1999 through 2000. However, considering that this model was also constructed with limited forcing information and modeling assumptions, these simulations are considered reasonable.

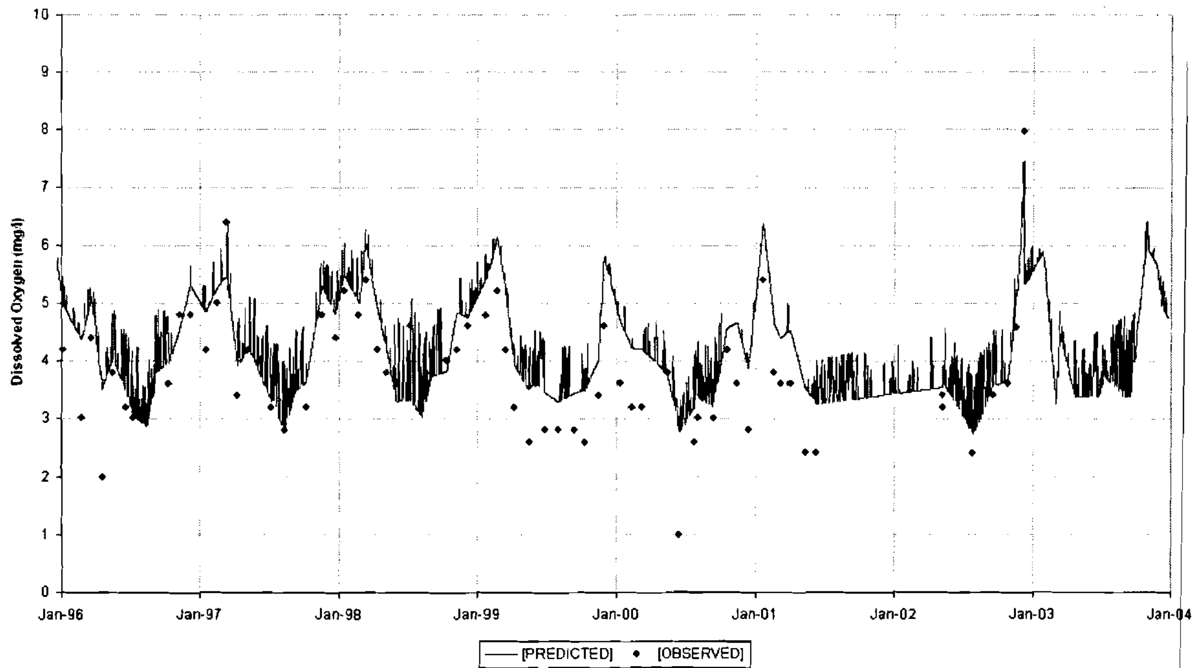

Figure 27. Segment 1, DO Calibration for Daughtrey Creek (1996-2003).

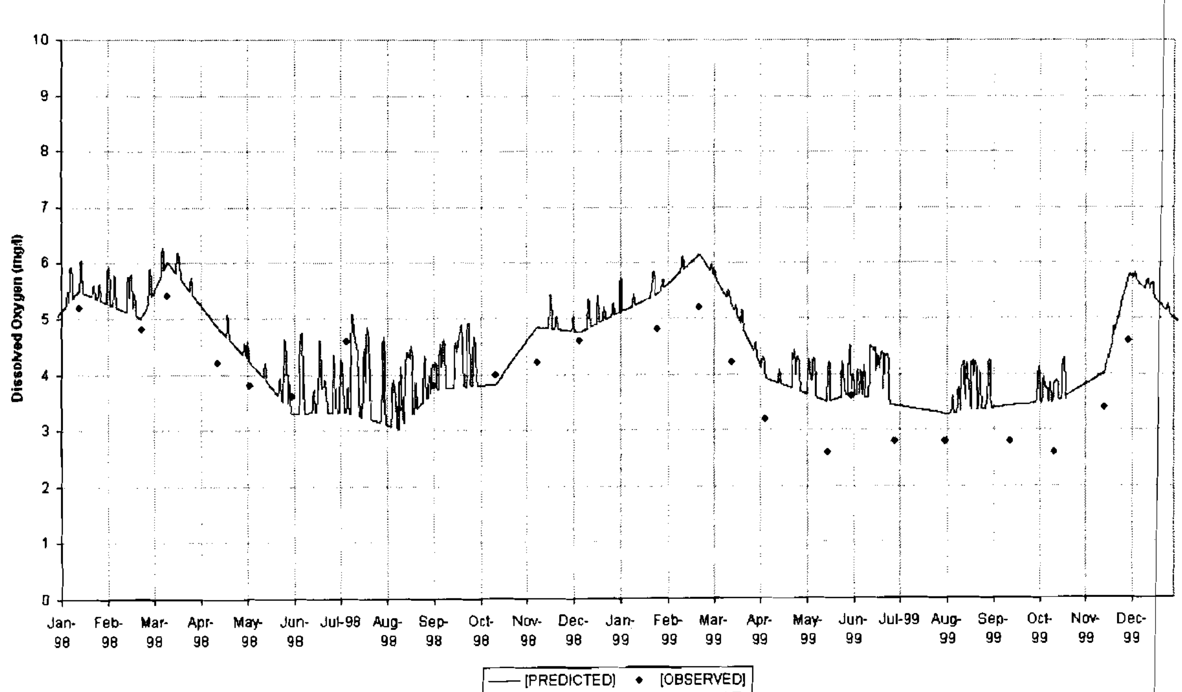

Figure 28. Segment 1, DO Calibration for Daughtrey Creek (1998-1999).

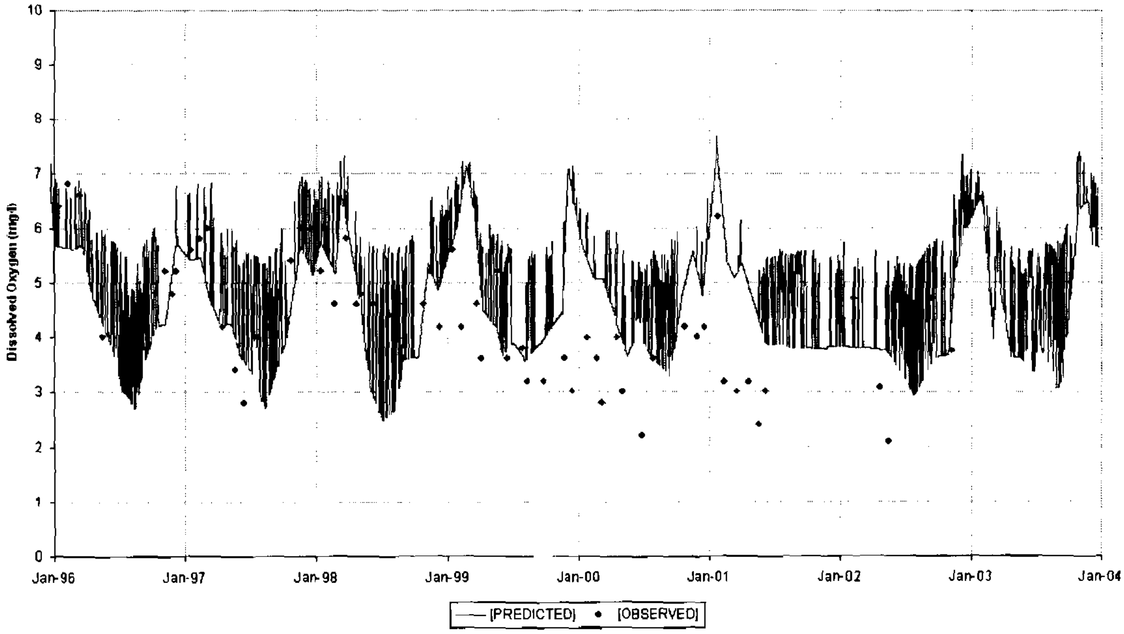

Figure 29. Segment 4, DO Calibration for Daughtrey Creek (1996-2003).

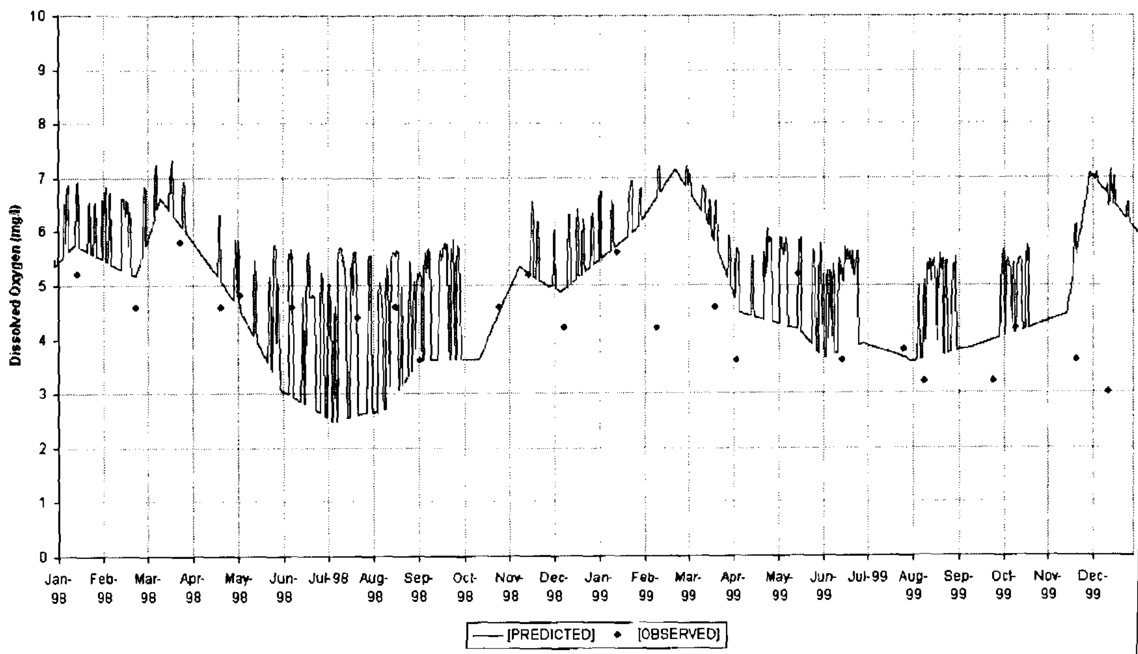

Figure 30. Segment 4, DO Calibration for Daughtrey Creek (1998-1999).

After the models were calibrated by changing SOD to predict D.O., the TMDL scenarios were evaluated iteratively. For these scenarios, the models were setup so that the dissolved oxygen coming into each system would meet the standard of 5.0 mg/l, and any violations would occur due to in-stream processes. Therefore, the dissolved oxygen forcing for all segments was set to 5.0 mg/L and the models were run to ensure that violations were still present.

Once the dissolved oxygen boundaries were modified, the next step was to reduce the SOD until acceptable dissolved oxygen levels were achieved (i.e. until the simulated D.O. concentrations met standards). In the Billy Creek model, this was accomplished when SOD in the critical segment was 1.0 g/m^2/day, while in the Daughtrey Creek model, acceptable D.O. levels were achieved when SOD was 1.2 g/m^2/day.

Figure 31 and Figure 32 show simulation results for segments 1 and 9 in Billy Creek at an SOD of 3.0 g/m^2/day (the SOD after calibration) and at 1.0 g/m^2/day (the target SOD). From these figures, it can be shown that the critical time period occurs during 1998. Segment 9 appears to be the critical location, as simulated (and measured) D.O. is consistently lower at Station 21FLEECOBILLCR20 near Ortiz Avenue, which is located at river mile 3.45. In addition, it was found that when SOD was lowered to meet D.O. at that station, D.O. was also met downstream in Segment 1. Figure 33 and Figure 34 show the simulation results for Daughtrey Creek at the calibration and target SOD levels. The downstream segment 4 appears to be the critical location, since D.O. is lower in that segment. It can be seen that at an SOD of 1.2 g/m^2/day, the dissolved oxygen at all segments remains at 5.0 mg/L or higher.

Since BOD is the causative agent, and the endpoint for TMDL allocations, SOD needed to be related back to BOD. Hence the goal was to determine what reduction in the watershed BOD loads would yield an SOD of 1.0 g/m^2/day in Billy Creek, and 1.2 g/m^2/day in Daughtrey Creek.

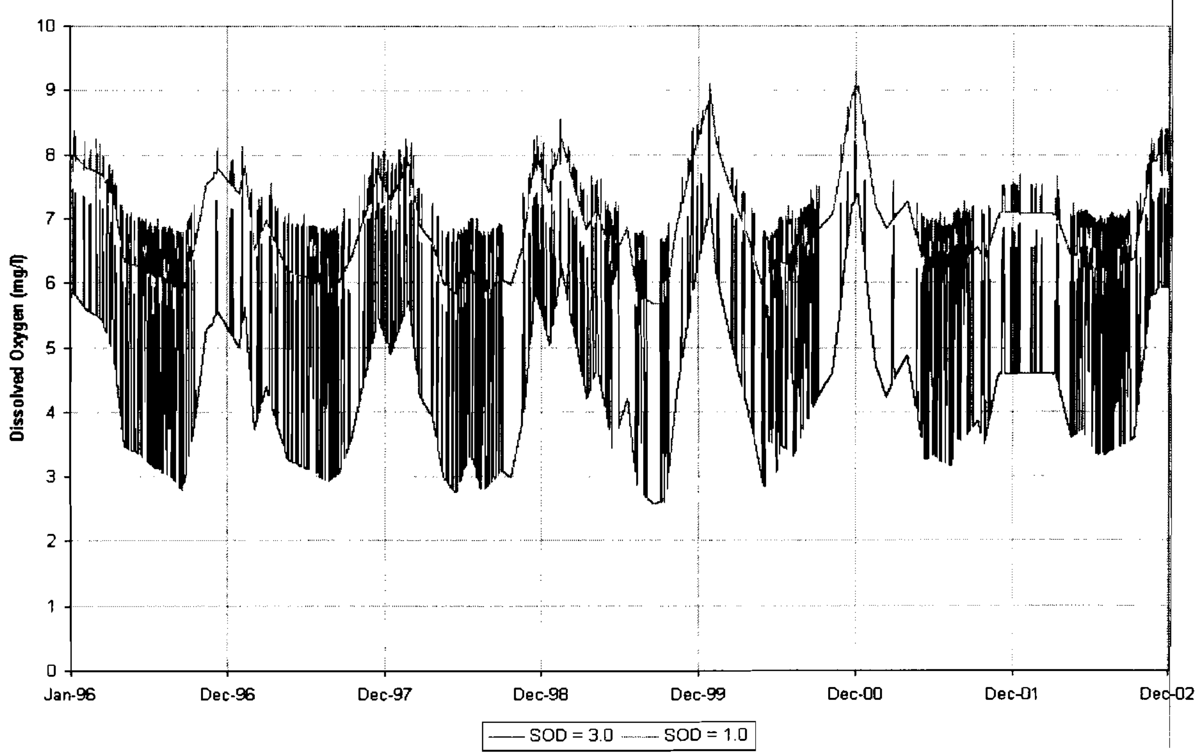

Figure 31. TMDL runs for Segment 1 in Billy Creek (1996-2002).

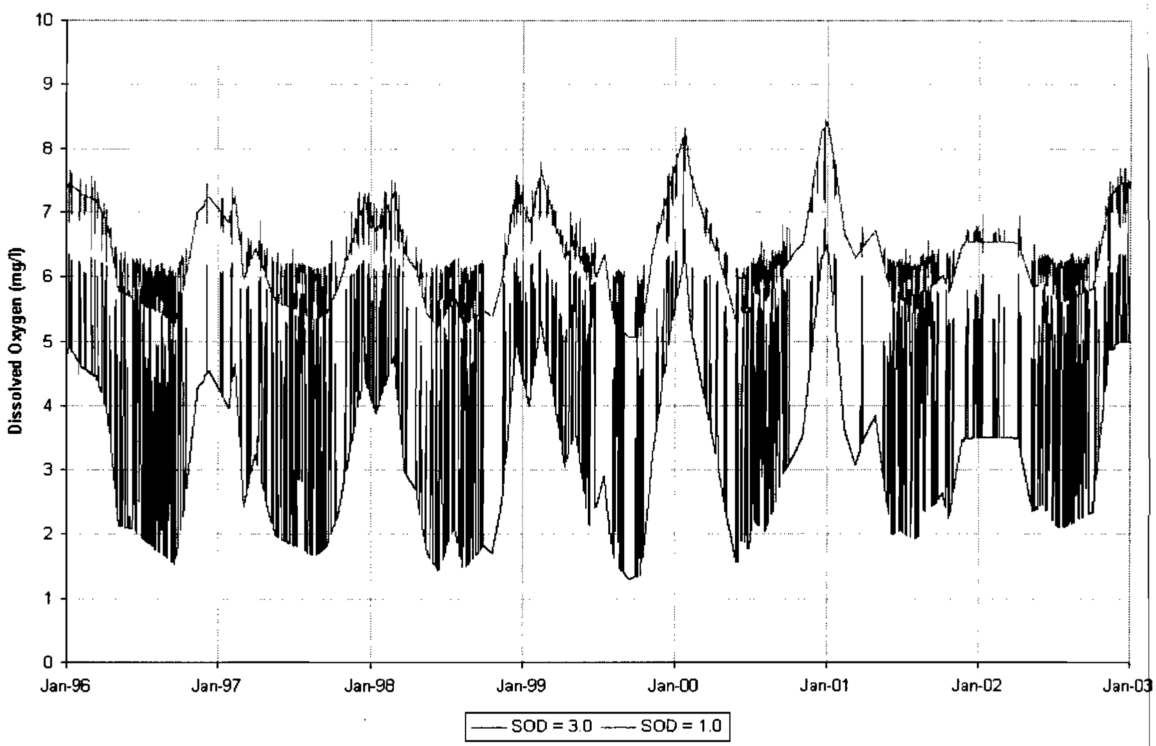

Figure 32. TMDL runs for Segment 9 in Billy Creek (1996-2002).

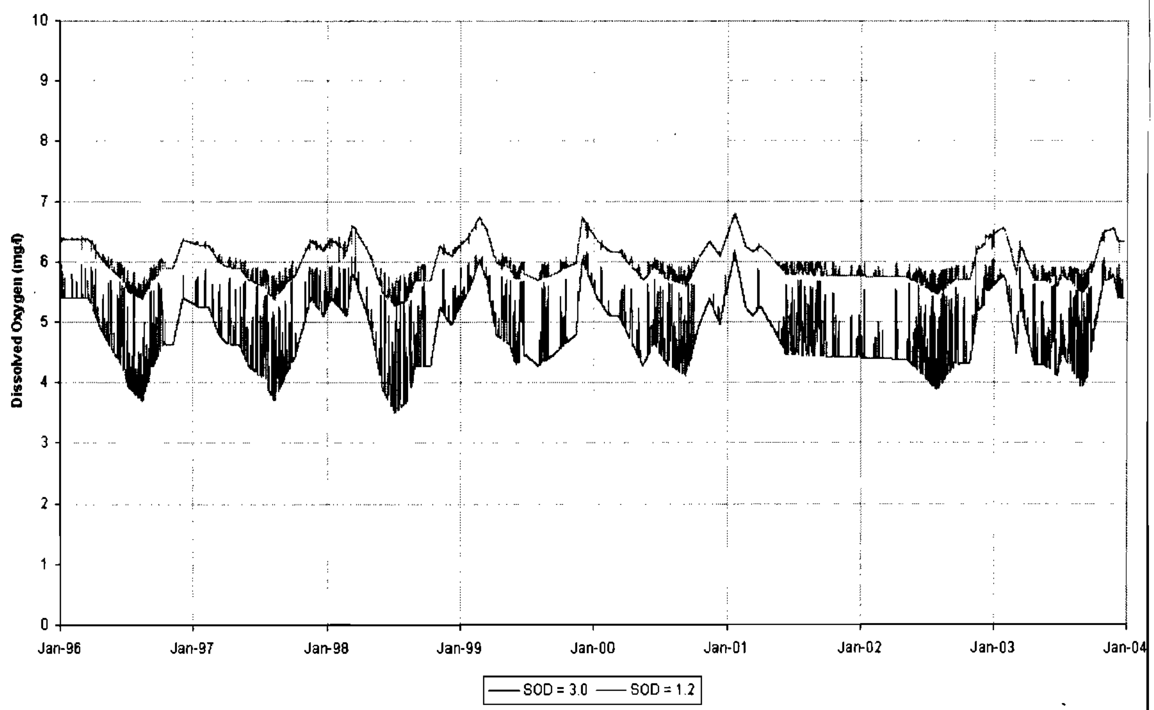

Figure 33. TMDL runs for Segment 1 in Daughtrey Creek (1996-2003).

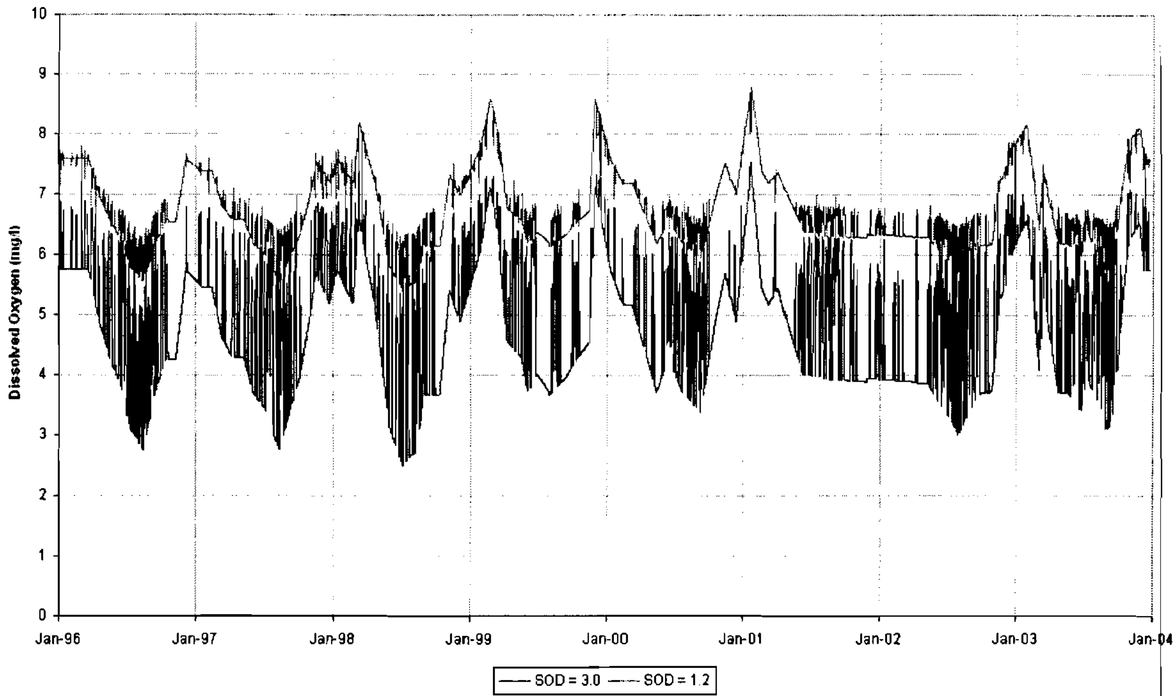

Figure 34. TMDL runs for Segment 4 in Daughtrey Creek (1996-2003).

Determination of Watershed Load Reductions

Currently, the WASP7 model does not have a sediment diagenesis algorithm to simulate the oxygen demand exerted by sediment on overylying water (SOD). Since SOD is an input to the WASP model, WASP cannot be used to predict SOD based on instream loads. Therefore, another model was used to establish a defensible link between instream loads of BOD and SOD. An SOD model developed by Quantitative Environmental Analysis (QEA) and modified by Dr. James Martin at Mississippi State University (MSU) was implemented to determine the relative change in SOD by reducing the watershed load of BOD (Martin, 2002).

For both streams, SOD spreadsheet models were run for the segments corresponding to the locations of water quality stations. For Billy Creek, the SOD spreadsheet model was run on segments 1 and 9, and it was determined that segment 9 was the critical segment. In other words, when SOD was low enough to meet the D.O. in segment 9, D.O. was met in all other segments. Table 18 and Figure 35 show results from the SOD spreadsheet model for CBOD reductions of 10, 25, 50, 75 and 90% in Billy Creek. Also shown is the SOD corrected to 20 degrees Celsius. For Daughtrey Creek, the SOD spreadsheet model was run on segments 1 and 4, and the downstream segment (segment 4) was used to determine the watershed load reduction. Table 19 and Figure 36 show results from the SOD spreadsheet model for CBOD reductions of 10, 25, 50, 75, and 90% in Segment 4 of Daughtrey Creek. The SOD corrected to 20 degrees Celsius is also shown.

Table 18. SOD Spreadsheet Model Results for Segment 9 in Billy Creek.

		Existing Conditions		10% Reduction		25% Reduction		50% Reduction		75% Reduction		90% Reduction	
	Temp	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC
1	21.54	1.87	1.66	1.77	1.57	1.59	1.42	1.23	1.09	0.73	0.65	0.37	0.32
30	18.92	1.58	1.71	1.50	1.63	1.37	1.49	1.10	1.19	0.69	0.75	0.35	0.38
60	19.68	1.04	1.07	1.01	1.03	0.95	0.97	0.82	0.84	0.58	0.59	0.32	0.33
90	23.39	1.35	1.04	1.30	1.00	1.20	0.93	0.99	0.76	0.66	0.51	0.36	0.28
120	27.66	1.39	0.77	1.33	0.74	1.22	0.68	1.00	0.56	0.67	0.37	0.37	0.20
150	28.47	1.59	0.83	1.51	0.79	1.38	0.72	1.11	0.58	0.71	0.37	0.38	0.20
180	27.24	1.61	0.92	1.54	0.88	1.40	0.80	1.13	0.65	0.72	0.41	0.38	0.22
210	27.65	1.80	1.00	1.71	0.95	1.55	0.86	1.22	0.68	0.75	0.42	0.39	0.21
240	27.52	0.74	0.41	0.72	0.40	0.69	0.39	0.62	0.35	0.48	0.27	0.30	0.17
270	27.68	1.28	0.71	1.23	0.68	1.14	0.63	0.95	0.53	0.64	0.35	0.35	0.19
300	24.27	1.52	1.09	1.45	1.04	1.33	0.96	1.07	0.77	0.67	0.48	0.34	0.25
330	18.34	1.56	1.77	1.49	1.69	1.36	1.55	1.09	1.24	0.68	0.78	0.35	0.40
360	19.18	1.42	1.51	1.36	1.45	1.26	1.34	1.02	1.09	0.64	0.69	0.33	0.35
390	16.45	1.50	1.97	1.44	1.89	1.32	1.74	1.07	1.40	0.67	0.88	0.34	0.45
420	19.51	1.54	1.59	1.46	1.52	1.34	1.39	1.07	1.11	0.68	0.71	0.36	0.37
450	22.65	1.54	1.26	1.47	1.20	1.34	1.09	1.08	0.88	0.68	0.56	0.36	0.29
480	22.48	1.80	1.49	1.70	1.41	1.54	1.27	1.20	0.99	0.73	0.61	0.38	0.31
510	24.41	0.90	0.64	0.88	0.62	0.83	0.59	0.72	0.52	0.53	0.38	0.30	0.21
540	21.86	1.68	1.45	1.59	1.38	1.45	1.26	1.16	1.01	0.74	0.64	0.39	0.34
570	29.09	0.80	0.40	0.77	0.38	0.74	0.37	0.65	0.32	0.49	0.25	0.31	0.15
600	30.12	1.46	0.67	1.40	0.64	1.29	0.59	1.05	0.48	0.69	0.32	0.38	0.17
630	29.12	1.14	0.57	1.11	0.55	1.04	0.51	0.88	0.44	0.60	0.30	0.32	0.16
660	21.36	1.71	1.54	1.62	1.46	1.48	1.33	1.16	1.04	0.70	0.63	0.35	0.32
700	18.04	1.71	1.99	1.62	1.89	1.48	1.72	1.16	1.35	0.70	0.81	0.35	0.41
	Average =	**1.44**	**1.17**	**1.37**	**1.12**	**1.26**	**1.02**	**1.02**	**0.83**	**0.66**	**0.53**	**0.35**	**0.28**

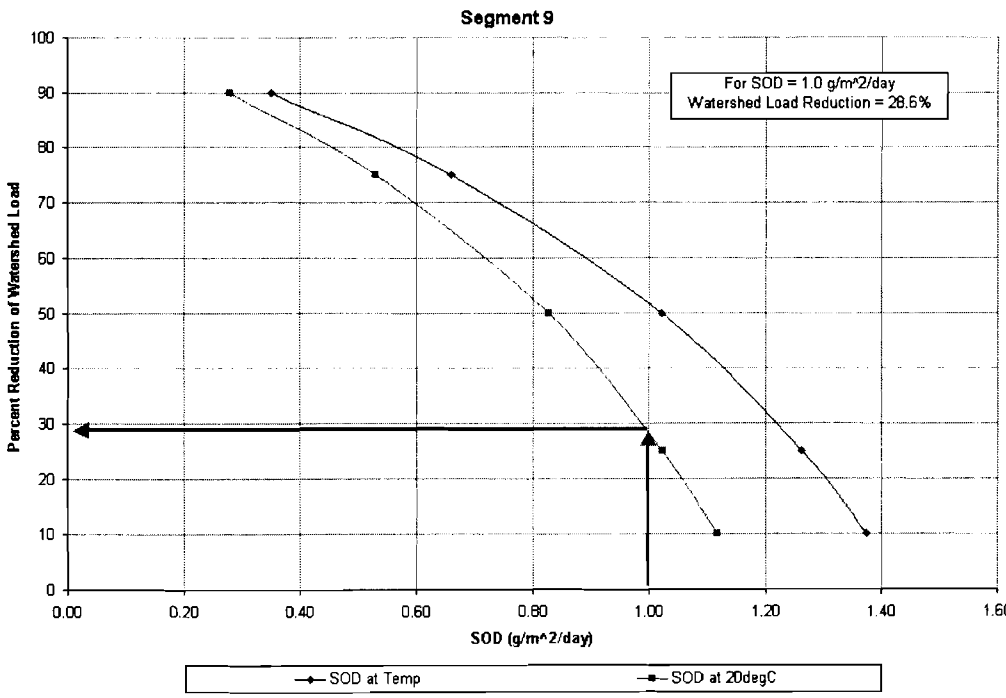

Figure 35. SOD Spreadsheet Model Results for Segment 9 in Billy Creek.

Table 19. SOD Spreadsheet Model Results for Segment 4 in Daughtrey Creek.

		Existing Conditions		10% Reduction		25% Reduction		50% Reduction		75% Reduction		90% Reduction	
	Temp	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC
1	20.50	1.87	1.80	1.76	1.69	1.57	1.51	1.18	1.14	0.69	0.67	0.36	0.35
30	21.40	1.82	1.63	1.71	1.54	1.53	1.37	1.16	1.04	0.67	0.60	0.35	0.31
60	18.37	1.50	1.70	1.43	1.62	1.29	1.46	1.00	1.13	0.60	0.68	0.31	0.36
90	21.27	1.63	1.48	1.54	1.39	1.38	1.25	1.06	0.96	0.64	0.58	0.33	0.30
120	25.96	1.70	1.07	1.60	1.01	1.44	0.91	1.10	0.69	0.66	0.42	0.35	0.22
150	29.76	1.77	0.84	1.66	0.79	1.49	0.70	1.13	0.53	0.67	0.32	0.35	0.17
180	30.69	1.90	0.84	1.80	0.79	1.61	0.71	1.23	0.54	0.73	0.32	0.38	0.17
210	29.17	1.99	0.98	1.87	0.92	1.67	0.82	1.26	0.62	0.74	0.36	0.38	0.19
240	27.01	1.41	0.82	1.35	0.79	1.25	0.73	1.02	0.59	0.65	0.38	0.34	0.20
270	25.78	1.72	1.10	1.63	1.04	1.47	0.94	1.14	0.73	0.68	0.44	0.35	0.23
300	21.82	1.66	1.45	1.58	1.37	1.42	1.24	1.10	0.96	0.66	0.57	0.34	0.30
330	22.18	1.76	1.49	1.66	1.40	1.49	1.26	1.13	0.96	0.67	0.56	0.35	0.29
360	19.77	1.82	1.85	1.71	1.74	1.53	1.56	1.17	1.19	0.69	0.70	0.36	0.37
390	24.05	1.70	1.24	1.60	1.17	1.44	1.06	1.10	0.81	0.65	0.48	0.34	0.25
420	18.45	1.71	1.92	1.61	1.81	1.44	1.62	1.09	1.22	0.64	0.72	0.34	0.38
450	23.58	1.72	1.30	1.61	1.23	1.44	1.10	1.09	0.83	0.65	0.49	0.34	0.26
480	25.24	1.89	1.26	1.77	1.18	1.56	1.04	1.16	0.77	0.67	0.45	0.35	0.23
510	26.54	1.32	0.80	1.27	0.77	1.17	0.71	0.94	0.57	0.59	0.36	0.32	0.19
540	26.45	1.95	1.18	1.83	1.11	1.64	1.00	1.24	0.76	0.73	0.45	0.38	0.23
570	26.69	1.56	0.93	1.49	0.89	1.36	0.81	1.09	0.65	0.68	0.40	0.36	0.21
600	25.95	1.83	1.16	1.73	1.09	1.55	0.98	1.19	0.75	0.71	0.45	0.37	0.23
630	24.95	1.56	1.06	1.48	1.01	1.36	0.93	1.07	0.73	0.66	0.45	0.34	0.23
660	22.16	1.76	1.49	1.66	1.41	1.49	1.26	1.13	0.95	0.66	0.56	0.34	0.29
700	16.68	1.76	2.28	1.66	2.14	1.49	1.92	1.13	1.45	0.66	0.85	0.34	0.44
	Average =	**1.72**	**1.32**	**1.62**	**1.25**	**1.46**	**1.12**	**1.12**	**0.86**	**0.67**	**0.51**	**0.35**	**0.27**

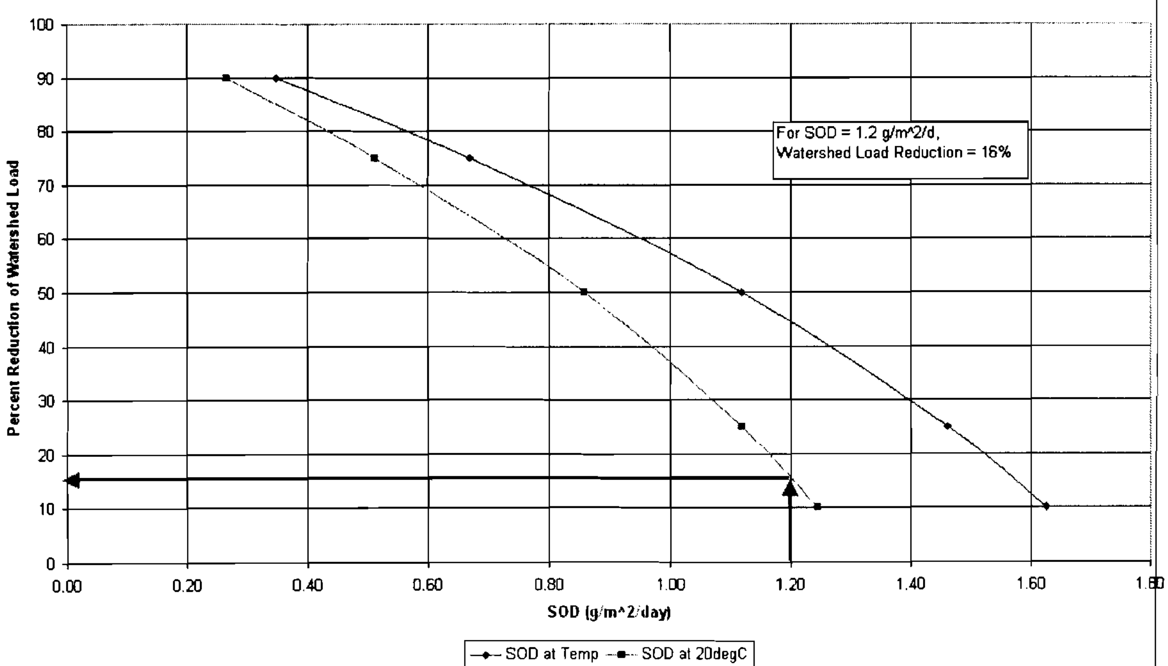

Figure 36. SOD Spreadsheet Model Results for Segment 4 in Daughtrey Creek.

Summary of Analytical Approach for Billy and Daughtrey Creeks

The Billy Creek (WBID 3240J) and Daughtrey Creek (WBID 3240F) waterbodies were placed on Florida's planning list for violations to the dissolved oxygen standard. Available data for development of model applications for both streams were limited. The observed data were used to adequately represent the system in a WASP7 application, with support from the GBMM and PLSM applications. WASP7 was set up to represent the basic Streeter-Phelps equations. SOD was chosen as the target, and these loads were related back to BOD. The resulting TMDL scenarios lead to a 29% percent reduction of the BOD load to Billy Creek, and a 16% reduction of BOD to Daughtrey Creek to meet the dissolved oxygen standards. Section 5.4 discusses the TMDL allocations in greater detail.

5.3.2 Ninemile Canal

The TMDLs for Ninemile Canal establish loads for nutrients and BOD to address nutrient and DO/BOD listed impairments. EPA has evaluated the waterbody to determine the 1) existing loading to the waterbody and 2) loading to the waterbody with a natural condition land use (forested and wetlands). There are no point sources in the waterbody.

The Pollutant Load Screening Model (PLSM) was used to calculate the nutrient and BOD loads entering Ninemile Canal from nonpoint sources. To develop the TMDL, anthropogenic landuses in the model were changed to natural, pre-development uses (i.e., wetlands and forest) and the resultant nutrient and BOD loads were calculated. The loads from the pre-development scenario were compared to those from existing landuse data and percent reductions were calculated. Due to the numerous canals and flow structures present, and the substantial alteration in natural flow patterns, it was concluded that additional analysis with WASP7 would not be practical or meaningful.

The purpose of a TMDL is to allocate pollutant loading such that water quality standards are achieved. The Clean Water Act at Section 303(d)(1)(C) states, "Such load shall be established at a level necessary to implement the applicable water quality standards ..." In expressing this TMDL, EPA must apply the applicable nutrient and dissolved oxygen water quality standards while also considering the definition of natural background and the directive not to abate natural conditions.

The natural background definition established a narrative criterion in cases where there is an absence of man-induced alterations, but then states that a natural background level can be established (through 62-302.800 FAC) based on a similar unaltered waterbody, or on historical pre-alteration data. Therefore, the Agency can apply a narrative natural background condition (unaltered) as the water quality criteria. In the TMDL context, without site-specific criteria, allocations would be targeted to achieve the natural background. Using a model, this can be achieved by removing all anthropogenic loading. Any allowance of increased loading beyond natural background would likely cause other than natural, and likely lower, dissolved oxygen levels which would not be a proper application of the Florida definition. However, because of the standard that prevents abatement of natural conditions (62-302.300(15) FAC), the TMDL must provide an allocation, where necessary, to allow for natural condition loading. Therefore, the natural background loadings for Ninemile Canal have been estimated, and the TMDLs are set equal to those loads.

PLSM Model

PLSM utilizes a computer-driven geographic information system framework to calculate constituent loads as the product of water quality concentration associated with certain land use practices, and runoff water volume associated with those same practices. The computational approach of the PLSM is similar to that of the Surface Water Management Model (SWMM) screening level tool. (Hendrickson, 2002) The model's nonpoint source pollutant concentrations are specific to one of 20 different land use classes. Water quantity is determined through a hybrid of the SCS curve number method, and is the product of rain volumes and a coefficient (referred to as the runoff coefficient, or RC, with values ranging from 0 to 0.9) relating the propensity of various land use and soil hydrologic group combinations to generate runoff. Each landuse category is assumed to transport a characteristic mass load of pollutant from one unit of area form one unit of effective rain. Figure 37 displays the computational framework of PLSM.

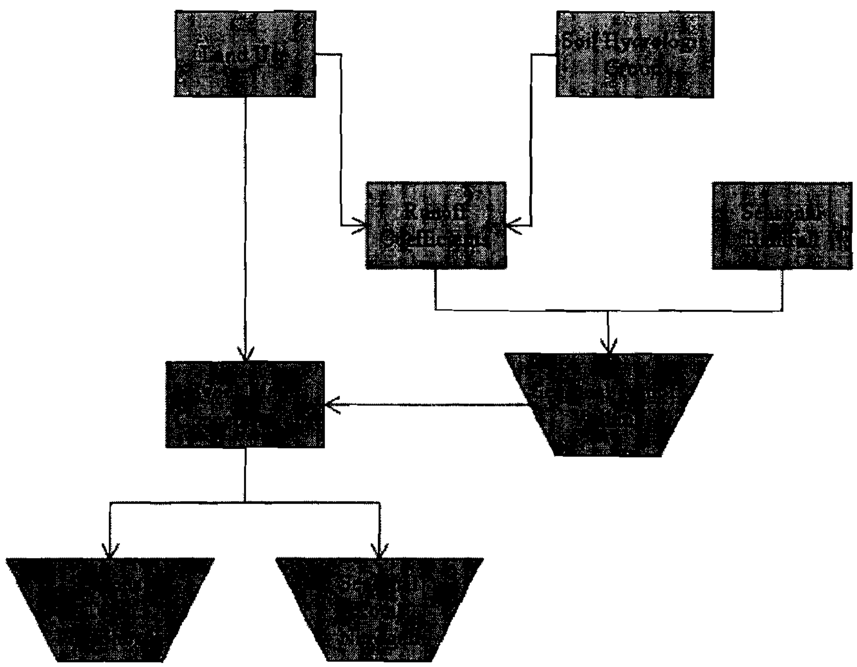

Figure 37. PLSM Conceptual Framework.

In this application of PLSM, the model was run within Microsoft Excel and it first calculated seasonal area-weighted runoff coefficients and flow-weighted concentrations for BOD based upon the area within the WBID of unique land use and soil hydrologic group combinations. This was accomplished by following the procedure outlined in Hendrickson and Konwinski (1998). The inputs required to administer PLSM are provided here. PLSM is calibrated by matching simulated pollutant loads and total discharge volumes to observed values.

Land Use

Data from the standard 2000 Florida Land Use, Cover and Forms Classification System (FLUCCS) code was obtained from SJRWMD and the South Florida Water Management District (SFWMD). This data was then aggregated into 20 distinct categories as defined in Table 20.

Table 20. Landuse Categories.

Category ID	Category Label	Category Description
1	LDR	Low Density Residential
2	MDR	Medium Density Residential
3	HDR	High Density Residential
4	LC	Commercial, Low
5	HC	Commercial, High
6	I	Industrial
7	M	Mining
8	RO	Range/Open Land
9	AGGEN	General, Agricultural
10	NAGEN	General, Non-Agricultural
91	PAST	Pasture
92	CROPS	Crops
93	CITRUS	Citrus
94	AGMISC	Agricultural, Miscellaneous
95	ANIM	Animal
101	FOR	Forested
102	SILV	Silviculture
103	WATER	Water
104	WETLDS	Wetlands
105	BARREN	Barren

Soils

The Soil Survey Geographic Database (SSURGO), developed by the Natural Resource Conservation Service, was used in PLSM and was obtained from SFWMD. Soils in PLSM are classified based specifically on their hydrologic group rating of A, B, C and D. Additional soil groups found within the dataset were group U (urban), which allows relatively average drainage, and Group X soils, for which drainage characteristics were unknown. Group U soils were ultimately handled as group C soils. Further, for this process, soils identified in the dataset as B/D and C/D soils were considered as B and C hydrologic group ratings, respectively. Landuse and soils data was then cross-referenced to provide the total area of each specific landuse-soils combination within each TMDL segment. These values were then applied directly to the model.

Rainfall

Rainfall data required to calculate runoff volumes and thus loads in PLSM was obtained from data collected at the Page Field Airport (FMY) in Fort Myers. Rainfall measurements were available from this station from 1966 to the present.

Long-term rainfall data collected at this station was processed to obtain overall seasonal averages. The seasons used were not the Julian seasons but modified seasons corresponding to hydrologic and meteorological patterns within Florida, and were comprised of a cool, moderately wet winter season from December through March characterized by regular frontal storm events; a hot, dry spring/summer from April through July; and a hot, wet summer/fall from August through November characterized by afternoon convective thunderstorms and tropical systems.

PLSM Calculations

Area-Weighted Runoff Coefficients

PLSM provides runoff coefficients based on the combination of soil type and land use inputs provided. Runoff coefficients are then multiplied by seasonal rainfall to determine a seasonal runoff volume from each particular combination of landuse and soil type. Runoff coefficients indicate the fraction of loads originating from the catchment that actually reach the stream. A value of 1 means the full load reaches the stream.

Event Mean Concentrations

The event mean concentration (EMC) reflects the average concentration of a parameter that would be found in surface water running off from an area of land with a consistent soil and land use. PLSM generates event mean concentrations for Total Nitrogen (TN), Total Phosphorus (TP), Biochemical Oxygen Demand (BOD), Total Inorganic Nitrogen (TIN), Phosphate (PO_4), Labile Total Organic Carbon (LTOC), and Refractory Total Organic Carbon (RTOC) based on calibrations as conducted in Hendrickson and Konwinski (1998) and the varying landuse-soils combinations that were provided. Event mean concentrations are then applied to the seasonal runoff volume to calculate average seasonal BOD loads for each landuse-soil combination. Total seasonal loads were calculated as the sum of all loads within a drainage basin.

It is important here to recognize that EMCs provided in the PLSM for Total Nitrogen and Total Phosphorus include both a labile (reactive) and refractory (inert) component. A supplemental study provided by J. Hendrickson, outlines a method by which nutrient loads may be partitioned into labile and refractory components. (Hendrickson, 2005) With these, it is possible to identify the total bioavailable nitrogen (TBN) and the total bioavailable phosphorus (TBP) loads which impact the system, and for which a TMDL may be calculated. Hendrickson proposes that TBN and TBP may be determined by the following relationships.

Provided that total organic nitrogen (TON) may be found by;

$$TON = TN - TIN \qquad \text{(Eq. 1)}$$

then, labile total organic nitrogen (LTON) and refractory total organic nitrogen (RTON) can be calculated as in Equations 2 and 3, respectively.

$$LTON = \left\{ \frac{\dfrac{LTOC}{4.5*TOC}}{\dfrac{RTOC}{37*TOC} + \dfrac{LTOC}{4.5*TOC}} \right\} * TON \qquad \text{(Eq. 2)}$$

$$RTON = \left\{ \frac{\dfrac{RTOC}{37*TOC}}{\dfrac{RTOC}{37*TOC} + \dfrac{LTOC}{4.5*TOC}} \right\} * TON \qquad \text{(Eq. 3)}$$

where;

$$RTON = TON - LTON \qquad \text{(Eq. 4)}$$

Similarly, assuming that total non-PO_4-phosphorus (TNOP) may be found by;

$$TNOP = TP - TPO_4 \qquad \text{(Eq. 5)}$$

then, labile total non-PO_4-phosphorus (LTNOP) and refractory total non-PO_4-phosphorus (RTNOP) can be calculated as in Equations 6 and 7, respectively.

$$LTNOP = \left\{ \frac{\frac{LTOC}{27*TOC}}{\frac{RTOC}{617*TOC} + \frac{LTOC}{27*TOC}} \right\} * TNOP \qquad \text{(Eq. 6)}$$

$$RTNOP = \left\{ \frac{\frac{RTOC}{617*TOC}}{\frac{RTOC}{617*TOC} + \frac{LTOC}{27*TOC}} \right\} * TNOP \qquad \text{(Eq. 7)}$$

where;

$$RTNOP = TNOP - LTNOP \qquad \text{(Eq. 8)}$$

Based on this series of relationships, the Total Bioavailable Nitrogen (TBN) and Total Bioavailable Phosphorus (TBP) may then be calculated by Equations 9 and 10, respectively. (Hendrickson, 2005)

$$TBN = LTON + TIN \qquad \text{(Eq. 9)}$$

$$TBP = LTNOP + PO_4 \qquad \text{(Eq. 10)}$$

These formulas will yield the same results whether they are applied to the EMCs provided in the PLSM, which are based on calibrations as conducted in Hendrickson and Konwinski (1998), or the component loads generated by the PLSM. For this study, the formulas were applied to the former to obtain EMCs specific to TBN and TBP for each landuse category. The subsequent event mean concentrations were applied to the seasonal runoff volume to calculate average seasonal TBN, TBP and BOD loads for each landuse-soil combination. The sum of all loads within a drainage basin were then calculated to develop total seasonal loads for TBN, TBP and BOD.

PLSM Results

BOD and nutrient loads for Ninemile Canal were calculated for the existing landuse conditions in the WBID for three seasons: season 1 (December through March); season 2 (April through July) and season 3 (August through November). Table 21 provides total daily and seasonal BOD and nutrient loads obtained from PLSM. The nutrient loads are for total bioavailable nitrogen (TBN) and total bioavailable phosphorus (TBP).

Table 21. Existing Loads from PLSM for Ninemile Canal (WBID 3237D).

	Season 1			Season 2			Season 3		
Current landuse scenario	Conc. (mg/L)	Daily Load (lb/day)	Seasonal Load (lb/season)	Conc. (mg/L)	Daily Load (lb/day)	Seasonal Load (lb/season)	Conc. (mg/L)	Daily Load (lb/day)	Seasonal Load (lb/season)
BOD	2.07	425.6	52348.6	1.74	516.6	63023.1	2.18	1482.8	180906.0
TBN	1.10	226.5	27863.2	1.04	308.7	37661.3	1.15	783.0	95526.6
TBP	0.16	32.2	3964.9	0.16	47.1	5740.4	0.29	200.1	24412.1

To better understand the impact of land use change on WBID 3237D, its land cover characteristics were adjusted to reflect a possible pre-development condition. Under this "natural conditions" scenario, all anthropogenic landuses were reverted to half forest and half wetlands and PLSM was re-run to predict the BOD and nutrient loads. The loads generated by applying a forested-wetlands scenario to WBID 3237D are provided in Table 22.

Table 22. Loads from PLSM for Ninemile Canal (WBID 3237D) under natural scenario.

	Season 1			Season 2			Season 3		
Forest-wetland scenario	Conc. (mg/L)	Daily Load (lb/day)	Seasonal Load (lb/season)	Conc. (mg/L)	Daily Load (lb/day)	Seasonal Load (lb/season)	Conc. (mg/L)	Daily Load (lb/day)	Seasonal Load (lb/season)
BOD	0.97	375.7	46205.7	0.95	721.6	88039.7	0.97	1086.1	132502.0
TBN	0.17	64.4	7919.5	0.28	214.9	26211.2	0.25	281.6	34350.4
TBP	0.05	18.3	2253.5	0.04	30.7	3743.0	0.06	66.6	8122.9

The TMDLs are the average annual loads for biochemical oxygen demand (BOD), total bioavailable nitrogen (TBN), and total bioavailable phosphorus (TBP) from the natural landcover scenario. These loads, expressed as pounds (lb) per day, are 731 lb/day BOD, 188 lb/day TBN and 39 lb/day TBP. Section 5.4 discusses the TMDL allocations in greater detail.

5.3.3 Lake Hicpochee

In order to develop a nutrient TMDL for Lake Hicpochee, the narrative criteria must first be translated to a numeric target. The nutrient endpoint for Lake Hicpochee was developed using a statistical approach that targets a "good" Trophic State Index (TSI<60) and relates that value back to an expected in-lake phosphorus concentration.

The biological productivity of lakes has long been classified into different trophic states. The Trophic State Index is based on the premise that changes in nutrient levels (measured by total phosphorus and total nitrogen) cause changes in algal biomass (measured by chlorophyll-*a*). The Trophic State Index is a way to quantify this relationship. A TSI concentration less than 60 is considered "good", while 60-69 is rated as "fair", and 70-100 is rated as "poor" (FDEP, 1996). TSI is calculated with the equations:

$$CHLA_{TSI} = 16.8 + [14.4 \times LN(CHLA)]$$
$$TN_{TSI} = 56 + [19.8 \times LN(TN)]$$
$$TN2_{TSI} = 10 \times [5.96 + 2.15 \times LN(TN + 0.0001)]$$
$$TP_{TSI} = [18.6 \times LN(TP \times 1000)] - 18.4$$
$$TP2_{TSI} = 10 \times [2.36 \times LN(TP \times 1000) - 2.38]$$

where CHLA is the chlorophyll concentration in µg/l; TP is the total phosphorus concentration in mg/l; TN is the total nitrogen concentration in mg/l, and LN is the natural log. The final TSI is the average of the TSI for chlorophyll ($CHLA_{TSI}$) and a TSI that accounts for nutrients ($NUTRI_{TSI}$). $NUTRI_{TSI}$ is determined from the TN and TP TSIs (or $TN2_{TSI}$ or $TP2_{TSI}$, depending on the TN/TP ratio), and considers the limiting nutrient based on the TN to TP ratio. The lake is considered phosphorus-limited when TN/TP is greater than 30; nitrogen-limited when TN/TP is less than 10; and co-limited when the ratio is between 10 and 30:

$$\text{If } TN/TP > 30, \text{ Then } NUTRI_{TSI} = TP2_{TSI}$$
$$\text{If } TN/TP < 10, \text{ Then } NUTRI_{TSI} = TN2_{TSI}$$
$$\text{If } 10 < TN/TP > 30, \text{ Then } NUTRI_{TSI} = (TP_{TSI} + TN_{TSI})/2$$

In order to predict phosphorus concentrations from TSI, paired measurements of phosphorus and chlorophyll were correlated. Because total phosphorus (TP) data were not available, measurements of dissolved orthophosphate (PO4) were used. Total phosphorus is a measure of all forms of phosphorus, including both dissolved and particulate fractions. Orthophosphate is a measure of the filterable (soluble, inorganic) fraction of phosphorus. It is the most reactive form of phosphorus and as such is the fraction available for uptake by plants. To establish a relationship between TP and PO4, data from the closest water quality stations upstream of Lake Hicpochee were reviewed. These two stations were 21FLSFWMCR-00.2T and 21FLSFWMS77. Both stations are located near the S-77 lock, and both had data for TP and PO4 measured on the same samples. The average ratio of PO4 to TP from these stations was used to estimate the fraction of total phosphorus that was orthophosphate in Lake Hicpochee. On average, PO4 was approximately one-quarter (24%) of total phosphorus. This ratio (0.24) was then used to estimate TP for Lake Hicpochee from its PO4 values as: TP (mgP/L) = PO4 (mgP/L) / 0.24.

The relationship between chlorophyll-a and total phosphorus was determined by averaging the data collected between 2001 and 2002 for each station. These statistics were developed on the 2001-2002 data because of the general quarterly sampling frequency and the fact that FAC 62-303.352 calls attention to annual average values of TSI. In 2003, data were collected on only one date, which was deemed insufficient to compute an annual average, especially considering the importance of having observations across the growing season. Chlorophyll values less than the limit of 1 µg/l were not used. With the data averaged by station, a single total phosphorus (estimated from PO4) and chlorophyll-a pairing represented each of the four water quality stations in the Lake Hicpochee WBID 3237C. These four points were plotted with chlorophyll-a on the Y-axis and total phosphorus on the X-axis, and a linear regression line was fit through them (Figure 38). The resulting equation was:

Chlorophyll-a (ug/L) = [88.309 * Total Phosphorus (mgP/L)] + 15.941

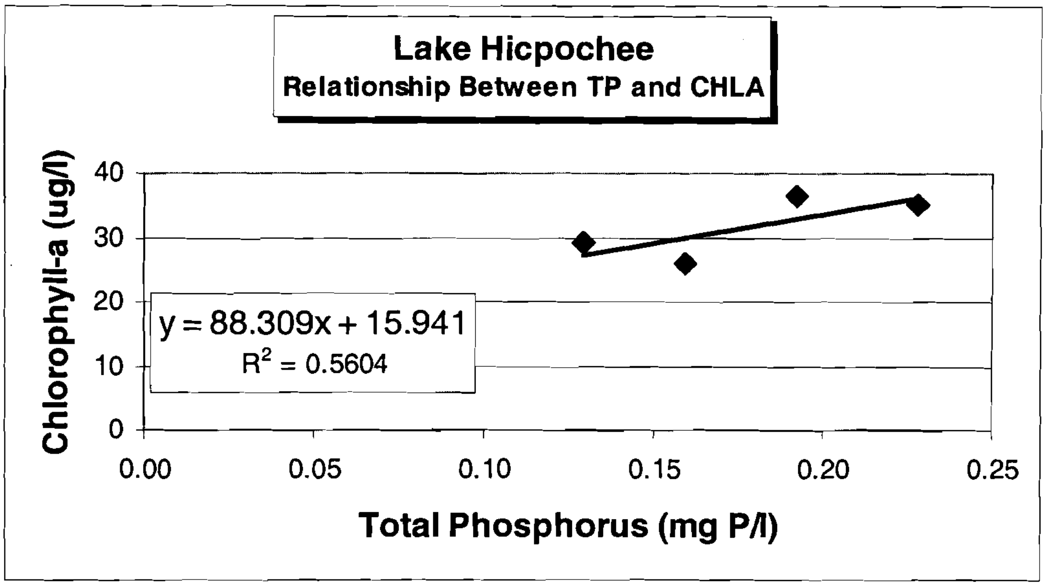

Figure 38. Relationship between estimated TP and Chlorophyll-a in WBID 3237C.

A representative range of TP values (0-0.15 mg/l) was selected for which to predict chlorophyll-a using the regression equation presented above. The resultant TSI was then calculated using the average total nitrogen measured at the WBID 3237C stations (TN= 2.32 mgN/L). The TSI calculation was not very sensitive to the nitrogen value used. This is because phosphorus concentrations are low around the target TSI of 60, resulting in the TSI calculation being driven by phosphorus-limitation in that range. A plot of total phosphorus and the predicted TSI values is presented in Figure 39. The TP concentration that correlated to a TSI < 60 was 0.035 mg/l. This concentration was therefore chosen as the nutrient target for Lake Hicpochee.

This target is similar to the in-lake phosphorus TMDL target of 0.040 mg/l (40 ppb) previously determined for Lake Okeechobee, which discharges to Lake Hicpochee via S-77. The C-43 canal that bisects WBID 3237C is bermed on both sides. As a result, most of the flow in the canal is water that was released from Lake Okeechobee. The marshy areas on either side of the canal mostly receive water as runoff from the adjacent land and groundwater seepage. The marsh stage does not necessarily follow the canal stage. The fact that the majority of water in the Lake Hicpochee canal is released from Lake Okeechobee, in addition to the results of the statistical analysis described above, support that a TP concentration target of 0.035 mg/l is appropriate for Lake Hicpochee. This target is a relatively conservative goal, but it appears to be achievable given that the 86^{th} percentile of estimated TP concentrations is 0.034 mg/l, meaning that approximately 86% of the estimated TP concentrations may already be below the target. Phosphorus reductions achieved through implementation of the Lake Okeechobee TMDL are expected to reduce the concentrations in Lake Hicpochee as well.

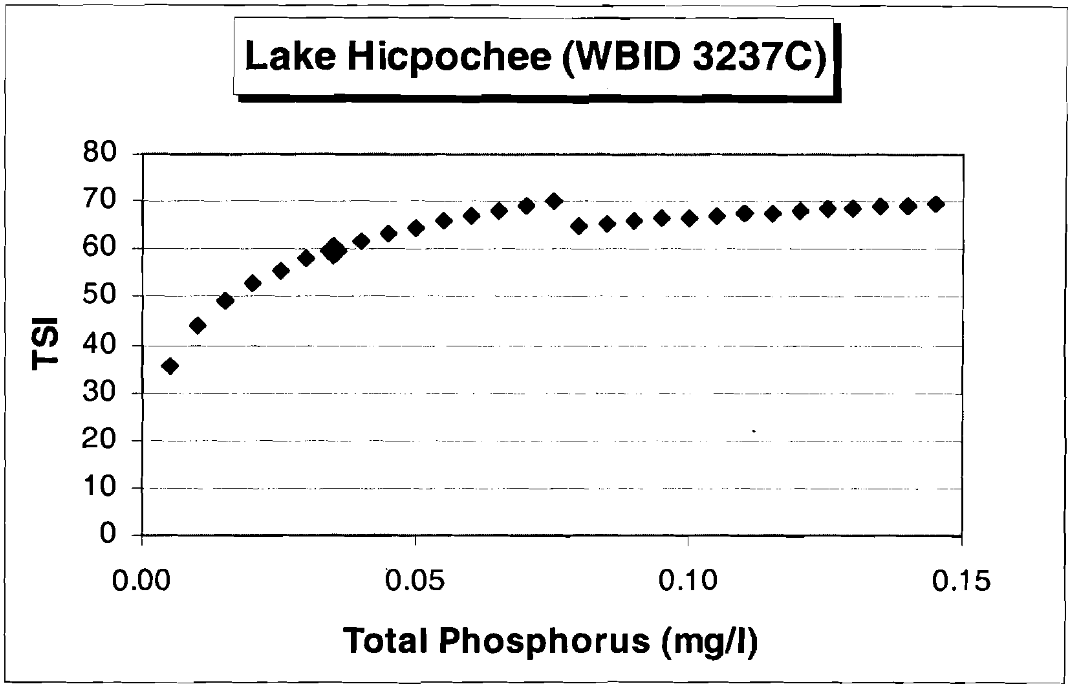

Figure 39. TSI Estimated from TP in Lake Hicpochee WBID 3237C.

5.4 Total Maximum Daily Loads

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), non-point source loads (Load Allocations), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \Sigma\, WLAs + \Sigma\, LAs + MOS$$

The objective of a TMDL is to allocate loads among the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time (e.g. pounds per day), toxicity, or <u>other appropriate measure</u>. The D.O. TMDLs for Billy Creek, Daughtrey Creek, and Ninemile Canal, as well as the nutrient TMDL for Ninemile Canal, are expressed as average annual loads in units of pounds (lb) per day, while the nutrient TMDL for Lake Hicpochee is expressed as an in-lake concentration. Components for the D.O. TMDLs are provided in Table 23, while Table 24 and Table 25 contain the components of the nutrient TMDLs for WBIDs 3237D and 3237C, respectively.

The dissolved oxygen TMDLs for Billy Creek, Daughtrey Creek, and Ninemile Canal are expressed as the loading of BOD5 that achieves the dissolved oxygen criteria. Since dissolved oxygen is not a pollutant, the TMDLs should allocate limitations for a pollutant that causes low dissolved oxygen. Therefore, the causative pollutant targeted for the TMDLs is biochemical oxygen demand (BOD).

Table 23. Components for DO TMDLs in WBIDs 3240J, 3240F, 3237D.

WBID	Parameter	TMDL (lb/day)	LA (lb/day)	WLA[1]		MOS (lb/day)	Percent Reduction[3]
				Continuous (lb/day)	MS4		
3240F	BOD	176	176	N/A[2]	N/A[2]	implicit	16%
3240J	BOD	305	305	N/A[2]	29%	implicit	29%
3237D	BOD	731	731	N/A[2]	N/A[2]	implicit	10%

Notes:
1. WLA component is separated into a load from continuous NPDES facilities (e.g., WWTPs) and a load from MS4s. Currently, there are no continuous discharge facilities or MS4 areas in WBIDs 3240F or 3237D. WBID 3240J is affected by Phase I MS4 permit #FL000035, which covers Lee County, the City of Cape Coral, and the City of Fort Myers. There are no continuous discharge facilities currently discharging to the surface waters of WBID 3240J.
2. N/A = not applicable.
3. Percent reduction in total BOD loading from current conditions to achieve the D.O. standard.

The nutrient TMDL for Ninemile Canal is expressed as the loads of total bioavailable nitrogen (TBN) and total bioavailable phosphorus (TBP) that represent natural conditions (i.e. removal of all anthropogenic contributions). Because of the standard that prevents abatement of natural conditions, the TMDL must provide an allocation, where necessary, to allow this natural loading. As such, these TMDLs are set to the natural background.

Table 24. Components for Nutrient TMDL in WBID 3237D.

WBID	Parameter	TMDL (lb/day)	LA[1] (lb/day)	WLA[1]		MOS (lb/day)	Percent Reduction[4]
				Continuous (mg/l)	MS4		
3237D	TBN	188	188	N/A[2]	N/A[2]	implicit	57%
	TBP	39	39	N/A[2]	N/A[2]	implicit	59%

Notes:
1. Represents natural background sources.
2. WLA component is separated into a load from continuous NPDES facilities (e.g., WWTPs) and a load from MS4s. Currently, there are no continuous facilities or MS4 areas in WBID 3237D.
3. N/A = not applicable.
4. Percent reduction in TBN or TBP loading from current conditions to meet the natural conditions standard.

Due to the fact that releases of water from Lake Okeechobee to the Caloosahatchee River are highly variable, the TMDL for nutrients in Lake Hicpochee is expressed as an in-lake concentration of total phosphorus. In addition, there is pending action from the U.S. Army Corps of Engineers regarding a reduction in the releases from Lake Okeechobee to Lake Hicpochee and the Caloosahatchee River. Given this uncertainty in future flow, a concentration-based TMDL was determined to be more practicable.

Table 25. Components for Nutrient TMDL in WBID 3237C.

WBID	Parameter	TMDL (mg/l)	LA (mg/l)	WLA[1]		MOS	Percent Reduction
				Continuous (mg/l)	MS4		
3237C	Total Phosphorus	0.035	0.035	N/A[2]	N/A[2]	implicit	91%

Notes:

1. WLA component is separated into a load from continuous NPDES facilities (e.g., WWTPs) and a load from MS4s. Currently, there are no continuous discharge facilities or MS4 areas in WBID 3237C.
2. N/A = not applicable
3. Percent reduction from current conditions to achieve the target concentration for phosphorus.

5.4.1 Waste Load Allocation

Only facilities discharging directly into streams and MS4 areas are assigned a WLA. The WLAs, if applicable, are expressed separately for continuous discharge facilities (e.g., WWTPs) and MS4 areas, as the former discharges during all weather conditions whereas the later discharges in response to storm events.

WBIDs 3237C (Lake Hicopochee), 3240F (Daughtrey Creek) and 3237D (Ninemile Canal) are not currently affected by NPDES facilities within or upstream of their WBIDs, nor are there any facilities currently discharging directly to surface water in WBID 3240J or any of Billy Creek's upstream tributaries. The Fort Myers Central WWTP (FL0021261) is a major facility designed to discharge up to 11 MGD. Although the WWTP is physically located within WBID 3240J, and discharges pollutants of concern for D.O. impairment (especially BOD and nutrients), its discharge is piped to the Caloosahatchee River estuary in WBID 3240B. Since Billy Creek is tidally-influenced, and this outfall location is just upstream of the junction with Billy Creek, the effect of this facility was included in the analysis for WBID 3240J (Billy Creek). However, because the outfall location is located outside of the Billy Creek WBID, no WLA is provided for it in the TMDL and all reductions are applied to the LA for nonpoint sources. Futhermore, the load from that point source does not appear to significantly affect the critical (upstream) segment on which the TMDL is based. The effect of that discharge on the Caloosahatchee River Estuary is outside the scope of the TMDL for WBID 3240J. The two WBIDs of the Caloosahatchee River Estuary nearest this outfall location, WBID 3240B (located above Billy Creek) and WBID 3240A (located below Billy Creek), are both verified as impaired for D.O. They have been assigned a medium priority by FDEP, and are scheduled for TMDL development in 2009. The permit for the Fort Myers WWTP acknowledges that FDEP may revise the permit and apply more stringent limitations at such time as a TMDL for the Caloosahatchee River Estuary is established.

The Phase I MS4 permit #:FL000035, which covers Lee County, the City of Cape Coral, and the City of Fort Myers, may affect WBID 3240J (Billy Creek). The WLA assigned to the MS4 area is expressed in terms of the percent reduction of CBOD loads required to attain the target. It is not possible to calculate the WLA in terms of load or isolate the loading discharging exclusively from MS4 areas.

5.4.2 Load Allocation

The primary mode of transport of nutrients and BOD to streams is during a storm event. Modification of the land surface from a pervious land cover to an impervious surface results in higher peak flow rates that wash nutrient and BOD-enriched water into the stream. Reductions in BOD loadings equal to the percent reductions provided in Table 23 throughout each watershed are expected to result in attainment of their dissolved oxygen standards. The load allocations for dissolved oxygen are expressed as the annual BOD loading in units of lb/day. Since the WBIDs are not affected by point sources, all of the TMDL loads are allocated to nonpoint sources in the LAs.

The nutrient load allocation for Ninemile Canal is expressed as the average annual TBN and TBP loading in units of lbs/day that achieves a natural background condition.

The nutrient load allocation for Lake Hicpochee is expressed as an in-lake concentration of total phosphorus. Reduction of total phosphorus concentrations to this target is expected to result in attainment of the narrative nutrient standard which calls for nutrient concentrations that do not cause an imbalance in the natural populations of aquatic flora or fauna.

5.4.3 Margin of Safety

There are two methods for incorporating a MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions to develop allocations; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations.

An implicit MOS was incorporated in the analyses for Billy Creek and Daughtrey Creek through conservative modeling assumptions. These assumptions include a conservative estimate of the F-ratio (3.0), which results in a greater BOD load than what would have been calculated using a smaller F-ratio. The range of F-ratios for municipal waste is typically between 1.2 and 3.2 (Thomann and Mueller, 1987). Besides using a ratio at the higher end of that range for the conversion of BOD to CBODu, characterizing the water as municipal waste would also result in a higher load. An additional margin of safety was introduced in Billy Creek by loading all of the point source discharge into the model, even though the actual discharge is to the Caloosahatchee River Estuary and any mixing into Billy Creek would be due to the tidal cycle.

For Ninemile Canal, an implicit MOS was incorporated by setting the TMDLs to natural background loadings and not reserving any additional assimilation capacity above those loads.

An implicit MOS was incorporated into the Lake Hicpochee nutrient TMDL by selecting a conservative Trophic State Index (TSI) as the target. The analysis was done such that the TSI would be less than 60 (i.e. it would achieve a "good" rating) even though a TSI score between 60 and 69 would not be considered impaired by Florida. Additionally, the TMDL is expressed as a concentration to reduce uncertainty introduced by the highly regulated and variable discharge that flows through Lake Hicpochee.

5.4.4 Critical Conditions and Seasonal Variation

The critical conditions can be defined as the environmental conditions requiring the largest reduction to meet standards. By achieving the reduction for critical conditions, water quality standards should be achieved during all other times. Seasonal variation must also be considered to ensure that water quality standards will be met during all seasons of the year.

The critical condition for non-point source loadings is typically an extended dry period followed by a rainfall runoff event. During the dry weather period, pollutants build up on the land surface, and are washed off by rainfall. The critical condition for point source loading occurs during periods of low stream flow when dilution is minimized. Although loading of nonpoint source pollutants contributing to a nutrient impairment may occur during a runoff event, the expression of that nutrient impairment is more likely to occur during warmer months.

For the Billy Creek, Daughtrey Creek, and Ninemile Canal TMDLs, specific critical conditions (wet or dry weather) could not be identified due to the limited amount of monitoring data. However, the modeling approach used in the Billy and Daughtrey Creek TMDLs takes this into account by identifying the location and time period during which dissolved oxygen concentrations were lowest in each stream, and then setting the TMDLs to ensure that standards were met during that and all other times. In addition, the Billy Creek, Daughtrey Creek, and Ninemile Canal PLSM models used long-term rainfall data (1966-2004) collected during all seasons in different years to estimate watershed loads.

Since nutrients can accumulate in waterbodies, it is important to consider their loading over longer periods (e.g. annual instead of daily loads). In Lake Hicpochee, critical conditions were incorporated into the TMDL development by using annual average phosphorus concentrations to determine the target concentration. These annual averages take into account each season of the year, including the growing season.

Seasonal variation was incorporated in the analysis by simulating loads during the various seasons and years. This incorporates changes in flow and meteorological conditions such as temperature, rainfall, and rainfall intensity.

5.4.5 Percent Reduction

The Billy and Daughtrey Creek percent reductions were calculated as the lowering of BOD loads from current conditions necessary to achieve the D.O. standard in each stream. Their existing conditions were based upon modeling results of the water quality stations in the WBIDs. The modeling time frame was chosen based upon the availability of monitoring data.

The percent reduction for Ninemile Canal reflects the amount of pollutant loading (BOD and nutrients) that would need to be reduced from existing loading conditions to return to natural background loading conditions. The existing conditions were characterized using predicted BOD and nutrient loads from the PLSM model and current land use data.

The percent reduction for Lake Hicpochee is from current conditions to achieve the target concentration for total phosphorus. The existing condition was characterized by the 90th percentile concentration of (estimated) total phosphorus (0.407 mg/l) from the available data.

Since there are no NPDES point sources or MS4 areas in WBIDs 3237C or 3240F, the entire reduction will be applied to their nonpoint sources. In WBID 3240J, the reduction will be applied to nonpoint sources and MS4 areas.

5.5 Recommendations

Determining the source of nutrients in waterbodies is the initial step to implementing a nutrient TMDL. FDEP employs the Basin Management Action Plan (B-MAP) as the mechanism for developing strategies to accomplish the necessary load reductions. Components of a B-MAP are:

- Allocations among stakeholders
- Listing of specific activities to achieve reductions
- Project initiation and completion timeliness
- Identification of funding opportunities
- Agreements
- Local ordinances
- Local water quality standards and permits
- Follow-up monitoring

As this TMDL is implemented, the Agency strongly encourages the development of site-specific dissolved oxygen and nutrient criteria for Ninemile Canal. In the absence of a site specific criteria, implementation of loading reductions should strive to achieve a natural background loading condition for the waterbody.

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APPENDIX A WATER QUALITY DATA REMARK CODES

Table A- 1. Guide to Water Quality Remark Codes (Rcode column in data tables)

Remark Code	Definition
A	Value reported is mean of two or more samples
B	Result based on colony counts outside the acceptable range
E	Extra sample taken in compositing process
I	The value reported is less than the practical quantification limit and greater than or equal to the method detection limit.
K	Off-scale low. Actual value not known, but known to be less than value shown
L	Off-scale high. Actual value not known, but known to be greater than value shown
Q	Sample held beyond normal holding time
T	Value reported is less than the criteria of detection
U	Material was analyzed for but not detected. Value stored is the limit of detection.
<	NAWQA – actual value is known to be less than the value shown